STUDY ON THE BIOLOGY AND FISHERY OF *POLYNEMUS HEPTADACTYLUS* CUV. & VAL.

A

Thesis

submitted to the

University of Bombay

for the degree

of

DOCTOR OF PHILOSOPHY

By

Miss. P.D. Nayak, M.Sc.,

Institute of Science,

BOMBAY

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C O N T E N T S

Pages

Part III. Fishery

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Appendix

A P P E N D I X

Supplementary papers only

Nayak, P.D. and Bal, D.V.	1955	The air-bladder and its relation with the auditory organ in *Hilsa toli* (Cuv. and Val.). *J. Univ. Bombay*, 23 (5) : 53-66
Bal, D.V., Nayak, P.D. and Varde, M.R.	1958	A comparative account of the air-bladder and the membranous labyrinth in some marine fishes. *J. Univ. Bombay*, 27 (3) : 1-21
Nayak, P.D.	1959	Some aspects of the fishery and biology of *Polydactylus indicus* (Shaw). *Indian J. Fish.*, 6 (2) :280-297
Nayak, P.D.	1959	Occurrence of hermaphroditism in *Polynemus heptadactylus* Cuv. and Val. *J. Mar. biol. Ass. India*, 1(2):
Kagwade, P.V. (alias Nayak, P.D.)	1965	Prawn catches by mechanised vessels in the trawling grounds of Bombay and Saurashtra (Abstract 119) *Symposium on Crustacea* held under the auspices of the Marine Biological Association of India at Ernakulam. p.70. (Full paper accepted for publication in the Proceedings of Symposium on Crustacea).

Synopsis of the thesis

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Miss P.D.Nayak, M.Sc.,

Department of Zoology,

Institute of Science, Bombay.

Bombay,

9-11-1964.

Department of Zoology,
Institute of Science
Bombay.

(C O P Y)

STUDY ON THE BIOLOGY AND FISHERY OF POLYNEMUS HEPTADACTYLUS CUV. AND VAL.

Synopsis

The fisheries of Polynemids, which are popularly known as thread-fins are supported by three commercially important species in Bombay viz. *Polynemus heptadactylus* cuv. and Val., *P. indicus* Shaw and *Eleutheronema tetradactylum* (Shaw). Of these *P. indicus* locally called 'Dara' and *E. tetradactylum*, 'Rawas' have captured the market, because of their large size and fairly high abundance in the seasonal inshore catches of the fishermen. The value of 'Dara' is hightened because of the demand in foreign countries to which it is exported in frozen or canned condition. Its large air bladder, which also finds a place in foreign markets as isinglass, fetches good price.

Although of much smaller size than the other two members, *P. heptadactylus*, known as 'Shende' has occupied a prominent place in the fisheries of Bombay especially since 1956 when the trawlers of the New India Fisheries Co. Ltd. began landing their catches of which this species formed 4 to 5 percent. The 'Dara' and 'Rawas' fisheries are seasonal and widely fluctuating, but 'Shende' occurs all through with a fairly steady fishery. While the trawlers catch the large sized mature ones in fair abundance, the well-known 'Dol' or bag nets land good quantities of smaller immature individuals, usually sun-dried and marketed. The 'Shende' catches by the New

India Fisheries vessels alone for 1957 contributed 147,294 kg. worth Rs.1,63,660 at Rs.20 a case of 18 kg. which was the then prevailing rate in Bombay. The total monetary returns from the harvests of the inshore and offshore fisheries in respect of this species are estimated to be very high.

Fairly adequate accounts on systematics of Polynemids in general are available in early published works of Day, Weber and de Beaufort and others, but very little is known of the biology and fisheries of the component species of this group. Whatever work has been done in the last two decades pertains only to two species, P. *indicus* and E. *tetradactylum*. At the time the study was initiated the taxonomic features of P. *heptadactylus* were not fully known and no information on any aspect of its biology and fishery was available. For proper management of this important fishery to ensure sustaining yields by exploitation on scientific lines, a knowledge of some aspects of biology as the span of life, rate of growth, food and feeding habits, age and size at sexual maturity, periodicity in spawning, regional and seasonal trends in commercial catches being essential, the present study was undertaken.

Between 1956 and 1959 samples of material for study were collected from the 'Dol' net catches at the fish landing places of Sassoon Docks and Versova; from the landings of the otter trawls operated by the Government of India vessels of the Deep Sea Fishing Station and from those of the bull-trawls operated by the vessels of New India Fisheries Co. Ltd., in Bombay and

Saurashtra waters.

Part I - Systematics and Distribution

The systematic position of the family Polynemidae has been reviewed. The various synonyms of *Polynemus heptadactylus* Cuv. and Val. used by different authors have been listed and a general description of the species has been given with some new characters not hitherto been recorded by earlier workers. The geographical distribution of the species in the tropical seas of the Atlantic, Indian and Pacific has been mentioned.

Part II - Biology

The food and feeding habits of *P. heptadactylus* have been studied in detail by points method. The variations in food composition between adults and juveniles and among adults in different seasons have been discussed. Crustaceans were found to ddminate in the food of both the juveniles and adults along with fair quantities of bony fishes.

Relationships between otolith length and scale length with the body length of the fish have been established. The age of fish and its rate of growth are determined by the growth checks on otoliths and scales. Further, 22,292 individual specimens have been measured to study the rate of growth by the Peterson's length frequency method.

The age composition of the fish in the commercial catches has been worked out.

Maturation studies deal with size at first sexual maturity, fecundity, period and frequency of spawning and ponderal index. Maturity key for determination of different stages of maturity in females has been prepared. The occurrence of different stages of maturity in the commercial catches obtained from different areas and different months has been discussed in relation to the breeding behaviour of the species.

A statistical relationship between length and weight of body in males and females treated separately has been established.

Hermaphroditism in this species is studied based on the morphology and histology of the ovotestes. The proportions of the hermaphrodite individuals in relation to normal individuals of both sexes in the samples in different months have been studied.

Part III - Fishery

This part deals with the fishing methods and the regions with the areas that are being fished for 'Shende' along with other catches. The catch data of the New India Fisheries bull-trawler landings for the period of April 1957 to March 1959 have been analysed. The intensity of fishing effort in different regions and the density of the populations in different areas on catch rates for units of fishing time in different months have been studied in detail. Particulars of analysis of all the hauls at different depths in different regions have also been given.

The influence of tides and lunar periodicity on the catch abundance has been discussed.

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The work on "study on the biology and fishery of *Polynemus heptadactylus* Cuv. and Val. was carried out in the department of zoology, Institute of Science, Bombay. To the best of my knowledge, the new morphological characters recorded, the observations of growth checks on otoliths and scales, the tracing of the year classes, the recruitment to fishable stocks and finding out the age composition of commercial catches are the first attempts for this species in India.

The determination of minimum size at first maturity and the spawning periodicity are additions to the knowledge of the biology of this fish. The phenomenon of hermaphroditism which has been studied in detail in this species is a new fact of much scientific interest.

The charting of the fishing grounds of *P. heptadactylus* in Bombay and Saurashtra waters, locating areas of maximum yields, finding out the depth-wise distribution in different regions and the influence of tides and the lunar periodicity on the catch abundance are the first attempts in the studies of its trawl fishery and are of outstanding value to the fishing industry in the expoitation of the resources.

Thus the present investigation will be a contribution to the knowledge of biology and fishery of one of the important marine food fishes of Bombay.

Preface

The thread-fins or Polynemids are a group of party pelagic and partly demersal fishes inhabiting the coastal waters throughout the tropical belt, extending upto considerable depths and even entering fairly often the estuaries and backwaters. The species do not form shoals for which reason they do not occur in great abundance but move in schools supporting fisheries of some magnitude. The species in general wherever they occur are classified as high class table fishes. Eight species under two genera are found in the Indian waters, viz., *Eleutheronema tetradactylum*, *Polynemus plebius*, *P. indicus*, *P. sextarius*, *P. paradiseus*, *P. sexifiles*, *P. xanthonemus* and *P. heptadactylus*. They vary much in length. Amongst the largest species the most important are *Polynemus indicus* and *Eleutheronema tetradactylum* which grow to over a metre. *P. heptadactylus*, *P. paradiseus* and *P. sextarius* are common among the smaller forms.

The extent of occurrence of Polynemids in the world fisheries is not known from the available records but in the inshore fishery of India this group is found to form about 0.82% (Banerji 1958) of the annual total marine fish landings. In the offshore fisheries of Bombay and Saurashtra waters *P. heptadactylus* comprises 4 to 5% and *P. indicus* about 1 to 10% or even more in the trawler catches (offshore catch data of the Central Marine Fisheries Research Institute, Mandampam Camp issued from time to time). The importance of the fishery of thread fins lies not so much in the bulk of the catches as in the quality of the fish which are considered delicious. The species supporting commercial fisheries of Bombay and Saurashtra waters are P.indicus popularly known as 'Dara', E.tetradactylum or 'Rawas' and P.heptadactylus or 'Shende'.

Both in the inshore and offshore fisheries of 'Dara' there has been a gradual decline in the catches during the past 8 years and even in 'Shende' a fall has been noticed in the landings in recent years. The need for stabilising the fisheries by carefully planned scientific exploitation is keenly felt.

Amongst the foremost systematists who dealt with Polynemids in general and the Indian species in particular are Cuvier and Valenciennes (1829), Bleeker (1849), Day (1878-88), Jordan and Starks (1917), Jordan (1923), Weber and de Beaufort (1922), Berg (1940), Smith (1949), Mendis (1954) and Munro (1955 & 58).

In the occasional observations of Bal and Pradhan (1945), Mookerjee et al (1946), Chacko (1949) Bapat and Bal (1952), Devanesan and Chidamberam (1953), and Mohamed (1955) food and feeding in E.tetradactylum, P.sextarius, P.indicus, and P.heptadactylus have been indicated. More detailed accounts are found on the food and feeding habits in E.tetradactylum (Malhotra, 1953) and in P.indicus (Mohamed, 1955, Karekar and Bal 1958). There is a paucity of information on the age and growth studies of Polynemids and the only reference available is the brief account by Nayak (1959) on P.indicus. Studies on the maturation and spawning of the Polynemid species are found in the works of Karandikar and Palekar (1950) on E.tetradactylum and of Mohamed (loc.cit.), Nayak (loc.cit.) and Karekar and Bal (1960) on P.indicus. Nayak (1959 b) has also recorded the occurrence of hermaphroditism in P.heptadactylus. On the development and larval studies of Polynemids mention may be made to the works of Sarojini and Malhotra (1952), Jones and Menon (1953), Kuthalingam (1960) and Marathe and Bal (1956a, b, 1958).

Very exhaustive accounts on the fisheries of 'Dara' in Bombay and Saurashtra waters are available in the published works of Mohamed (1955), Jayaraman et al (1959) and Nayak (1959a). Bhimachar (1959) has referred to thread fins, namely, E.tetradactylum, P.indicus and P.paradiseus being amongst the species contributing to the major fisheries of Sunderbans. In the trawling grounds of Pakistan, Qureshi and Burney (1952) have estimated that thread-fins, P.indicus and P.plebeius comprised 2.5% of the total landings. However, detailed biological knowledge of any member of this group or the group as a whole was lacking at the time when this work was initiated.

In the fisheries research schemes of the Central and State Governments considerable progress has been achieved in elucidating information on the biology and fisheries of the more important fishes from the point of view of quantitative abundance in catches, like the sardines, mackerel and prawns, but the coverage in respect of the lesser groups as the Polynemids is not sufficiently adequate.

An attempt has been made to redescribe Polynemus heptadactylus and discuss its taxonomic position. Keys to the field identification of the Indian species have been prepared. Various aspects of the biology as food and feeding habits, age and growth and spawning periodicity have been studied along with related problems. Commercial catches from the inshore and offshore regions have been analysed; relative regional and seasonal abundance of this species has been assessed.

The results obtained are incorporated in the thesis which it is hoped, will be of value not only in helping management of the fishery of this species in this region but also fill in the gaps in our existing knowledge of the biological behaviour of the widely distributed group of Polynemids.

P A R T - I

SYSTEMATICS AND DISTRIBUTION

Systematics

Polynemus heptadactylus belongs to the family Polynemidae under the group Polynemiformes, order Acanthopterygii of the subclass Teleostei (Day, 1889). This family has been treated by Weber and de Beaufort (1922) under the order Persesoces which also includes the families Sphyraenidae, Mugilidae and Atherinidae. The same four families have been included by Jordan (1923), Irvine (1947) and Herre (1953) under the order Percomorphi. The order Mugiloidea of Smith (1949) is synonymous with the order Persesoces of Weber and de Beaufort (loc. cit.). The group Polynemiformes of Day has been raised to the rank of an order by Berg (1940), Mendis (1954) and Munro (1955 & 1958). The order Persesoces, Percomorphi or Mugiloidea is divided into families based on the presence or absence of free pectoral filaments, position of the eyes and the number of spines in the first dorsal. The Polynemidae are distinguished from all other families under the order in the presence of a varying number of pectoral filaments articulating with a bone formed by the union of pterygials and anchylosed with the scapular and coracoid bones.

In the following account the salient characters of the family Polynemidae are given. Seven branchiostegals. Oblong body which is somewhat compressed. Eyes large, lateral and more or less covered by adipose lids. Mouth ventral to a prominent snout and having a lateral cleft. Villiform teeth on jaws, palatines and sometimes on vomer. Two short distinctly separated dorsal fins; first with 7 to 8 spines and the second with 11 to 15 rays. Several mobile articulated tactile filaments below the pectoral fins; ventrals thoracic with one spine and five rays. Caudal fin deeply forked. Scales ctenoid or cycloid on head and body, minute scales sometimes on second dorsal, anal, ventral and caudal. Lateral line continuous and continued on to the caudal fin. Muciferous system on the head well developed. Vertebrae 24. Air bladder when present varying in form and structure.

The Indian species of Polynemidae are included under one genus *Polynemus* by Day (loc. cit.), they being *Polynemus tetradactylus*, *P. plebius*, *P. indicus*, *P. sextarius*, *P. sexifilis*, *P. xanthonemus*, *P. paradiseus* and *P. heptadactylus*. These species are recogniseble principally on the number and size of the pectoral filaments which vary from 4-7. The Indo-Australian species of Polynemids are grouped by Weber and de Beaufort (loc. cit.) into two genera, viz., *Eleutheronema* and *Polynemus*. Their classification is based on the development of the lower lip, teeth on the jaws, number of pectoral filaments, simple or divided nature of pectoral rays and the length of the pectorals. Out of the 17 species described by them 6 are identical with the Indian species of Day.

Both the genera *Eleutheronema* and *Polynemus* occur in

Indian waters. Eleutheronema is characterised by the lower lip being developed only at the corner of the mouth, teeth extending to the exterior part of the jaws and the number of pectoral filaments being either 3 or 4 whereas Polynemus has the lower lip well developed, but not continued to symphysis, teeth in jaws not extending to the exterior and pectoral filaments 5 or more.

In describing the Indian species, the generic name Polydactylus has also been used by some workers. Meyers (1936) observes that Polynemus Linneus, Polydactylus Lacepede, Eleutheronema Bleeker, Polistonemus Gill, Pentanemus Gunther, Galeoides Gunther and Filimanus Meyers should be tentatively regarded as valid genera. Of these the first three generic names are applicable to the Indian species of the family Polynemidae. According to him in Polydactylus the lateral line is straight, the pectoral fin is inserted low, the upper part of its base being situated much below the mid-lateral line of the body, lower lip extends far forward, teeth are absent on the outer side of the jaws, maxillaries are distinctly widened at the ends and a sharp pectoral fold is present extending to the base of one or more pectoral filaments, the number of which is variable whereas in Polynemus the anterior part of the lateral line rises in a long low curve, the sharp pectoral fin is inserted high, pectoral fold is absent and the number of pectoral filaments is seven. The recognition of Polydactylus Lacepede as a valid genus is still controversial and Meyer's definition of the characters as stated by the author are tentative. Considering Polydactylus Lacepede as being synonymous with Polynemus Linneus, the following key to the identification of the Indian species of Polynemidae is prepared after Day and Weber and de Beaufort with slight changes.

Key to the Identification of the Indian Genera of Polynemidae

1. Lower lip absent except at the corners of the mouth, teeth extending on to the exterior part of the jaws, free pectoral filaments not more than four .... Eleutheronema

2. Lower lip well developed and extending forward but not to symphysis, teeth not extending to exterior part of jaws, free pectoral filaments five or more .... Polynemus

Key to the Field Identification of the Indian Species of Eleutheronema

1. Four free pectoral filaments .... E. tetradactylum

Key to the Field Identification of the Indian Species of *Polynemus*

1. Five free pectoral filaments

    A. Free pectoral filaments reaching to the end of ventral fin, pectoral rays undivided; vomerine teeth present; L.l. 60-65; colour golden with grey longitudinal bands .... *P. plebeius*

    B. Free pectoral filaments reaching to about anal fin, pectoral rays some divided and others undivided; vertical fins dark edged; L.l. 70-75 .... *P. indicus*

2. Six free pectoral filaments

    A. Free pectoral filaments extending upto middle or end of the ventral fin, pectoral rays mostly divided; vomerine teeth absent (shoulder bloch present) ..... *P. sextarius*

    B. Free pectoral rays extending beyond the ventral fin

        (a) Pectoral fin black, dorsal and anal fins black edged; no shoulder bloch .... *P. sexfilis*

        (b) Fins edged black; no shoulder bloch .... *P. xanthonemus*

3. Seven free pectoral filaments

A. Free pectoral filaments very long, the first three twice as long as the body; L.l. 70 .... *P.paradiseus*

B. Free pectoral filaments extending to about the end of the ventrals, pectoral rays unbranched; L.l. 48-60 .... *P.heptadactylus*

Synonymy and Specific Characters of P.heptadactylus

Polynemus heptadactylus	Cuvier and Valenciennes, Hist. Nat. poissons, III. 1829, pp. 300
Polynemus heptadactylus	Bleeker, Verh. Bat. Gen. XXII 1849, Bijdrage Percoiden, pp. 60.
Polynemus heptadactylus	Cantor, Journ. Asiat. Soc. Bengal, XVIII. 1850, pp. 1016.
Polynemus heptadactylus	Day, Fishes of India, 1878-1888, pp. 177.
Trichidion heptadactylum	Jordan and Starks, Ann. Carnegie Mus. XI. 1917, pp. 455.
Polynemus heptadactylus	Mendis, Fishes of Ceylon, 1954, pp. 161.
Polynemus heptadactylus	Munro, Mar. and Freshw. Fish. Ceylon, 1955, pp. 96.
Polydactylus heptadactylus	Munro, Papua and New Guinea Agric. Journ. X, No. 4, 1958, pp. 157.

The following description is based on actual observations on the various characters of a large number of individuals ranging from 267 mm to 296 mm in total length (Fig. 1).

D_1.VIII, D_2.I.12-14 (13 most common), A.III.12, P.12-14 (12 or 13 most common) + 7, V.I . 5, L.l. 48-52, L.tr. 5/1/10.

Length of head $\frac{1}{3.8 - 4.1}$ and height $\frac{1}{4.1 - 4.5}$ of the total length. Eye diameter $\frac{1}{3.9 - 4.1}$ of the length of head and one apart; pupil $\frac{1}{1.8 - 2.1}$ of the eye diameter. Maxilla $\frac{1}{2.1 - 2.4}$ of the head length. Preopercle with strong serrations, angle at the hind border rounded and with a prominent spine. On the shoulder a strong spine at the commencement of the lateral line. Jaws, vomer and palate with villiform teeth.

The first dorsal fin with 8 spines, the first spine small, second stout and third the longest being about 2/3 of body height. The second dorsal concave, anteriorly high; its spine is 2/3 more than the second spine of the first dorsal. Pectoral rays unbranched, length of pectoral fin slightly over 3/4 the height of body, free pectoral filaments reaching ventral or extend beyond, upper filaments longer. Ventral fin extends upto anus and equals first dorsal. Caudal deeply

1. a) *Polynemus heptadactylus* Cuv. & Val. x 1/2

b) *P. heptadactylus* showing air-bladder in situ. x 1/3


1b

forked. Colour golden yellow, pectoral very black, edges of first and second dorsals and caudal black; similarly pigmented are the lower half of the anal and the tip of the ventral.

In addition to the above characters, a distinct black shoulder spot (Fig.1a) and the presence of a large air bladder have been noted and recorded here for the first time in this species. In fish measuring 296 mm. in total length the shoulder spot measures 18 mm long and 10 mm broad extending over five scales at the anterior region of the lateral line; in a fish of 56 mm in total length it measured 3 mm by 2 mm in exactly the same position in reference to scales on the lateral line. The air bladder (Fig.1b) in this species is silvery white, simple being devoid of any diverticulum and single chambered and situated in the body cavity beneath the vertebral column, ventral to the kidneys. It is of a closed type met with in Physoclistei. When full it is narrow in front and behind but dorsally straight and broadest in about the middle region of the body cavity.

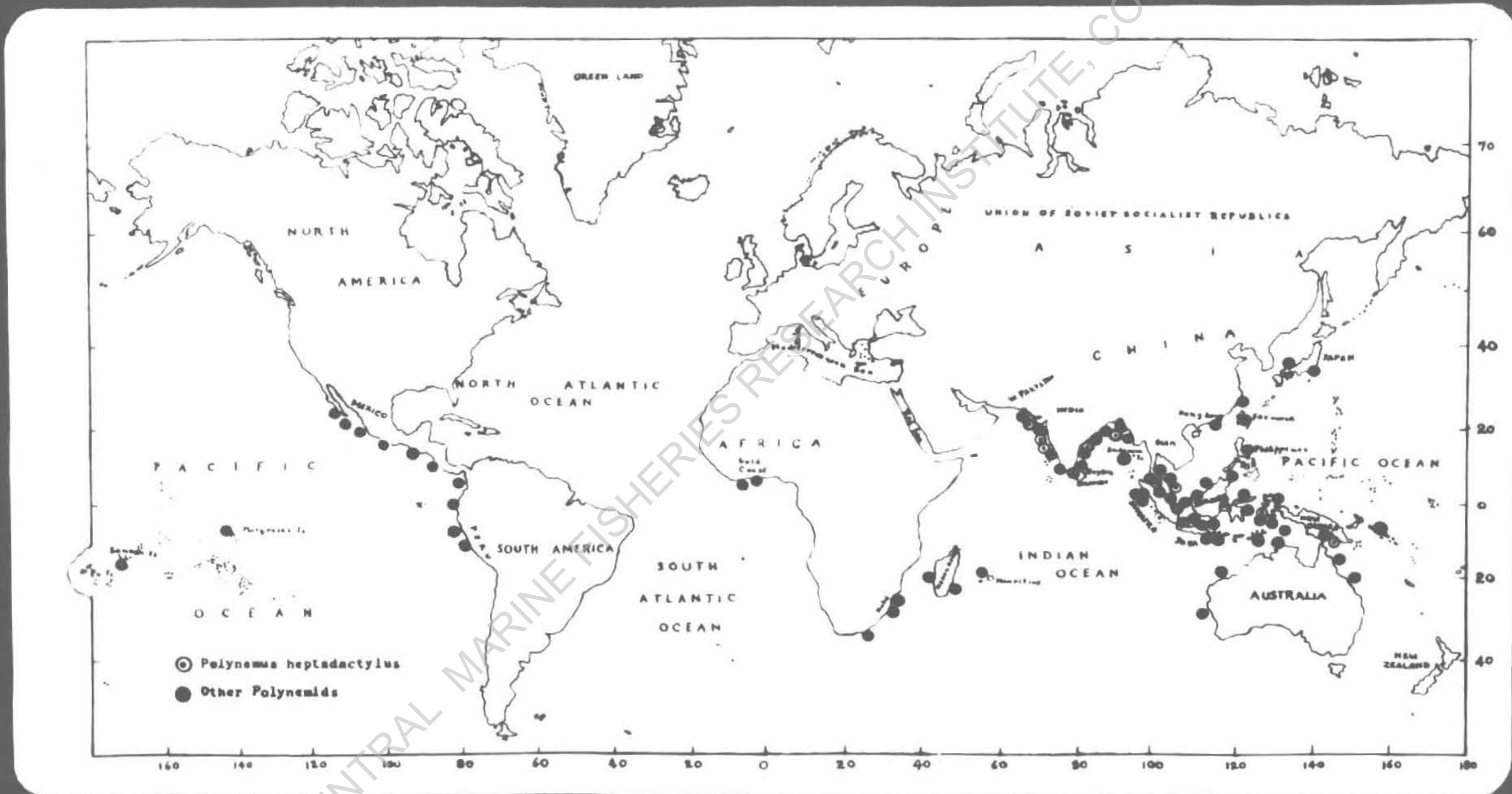
Day (loc. cit.) has stated that the air bladder is absent in Polynemus heptadactylus and other species, viz. P. tetradactylus, P. xanthonemus and P. paradesius but present in the remaining four species described by him.

Distribution

The family Polynemidae is widely distributed in the tropical parts of the Atlantic, Indian and Pacific oceans and is not so far known to occur in the Red Sea (Fig. 2). Members of this family are recorded from the eastern tropical Pacific ocean from the upper portion of the Gulf of California to Northern Peru (Klawe and Alverson, 1964). Some Polynemids occur in the Atlantic ocean off the Gold Coast (Irvine, 1947). From the works of Day (1889), Weber and de Beaufort (1922), Meyers (1936), Smith (1949), Herry (1953), Mendis (1954) and Munro (1955), Polynemids have been observed in the Indian ocean from the coasts of south Africa, Madagascar, Mauritius, Indian Peninsula, Andamans, Burma and Singapore. They are known from the Indonesian and adjacent islands, north Borneo, Celebes, Philippines, New Guinea and Australia in the Indo-Pacific waters. They are found in the western part of Pacific ocean in Japan, Formosa, Hong Kong and Fiji and Samoa Islands. Though widely distributed, they show greater concentration in the Indo-Pacific region.

From the published literature the distribution of *P. heptadactylus* appears to be restricted to only Indo-Australian waters. Though tropical in habitat like other members of the same family, this species is not recorded so far from the African and Philippine waters. It is found to inhabit the seas of India, Burma, Ceylon, Penang, Malay Peninsula, Moluccos,

2. Geographical Distribution of Polynemids.


GREEN LAND
NORTH
AMERICA
UNION OF SOVIET SOCIALIST REPUBLICS
A S I A
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OCEAN
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PACIFIC
OCEAN
PACIFIC OCEAN
SOUTH AMERICA
SOUTH
ATLANTIC
OCEAN
INDIAN
OCEAN
AUSTRALIA
NEW ZEALAND
Polynemus heptadactylus
Other Polynemids
70
60
40
20
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Borneo, Java and Sumatra. In the New Guinea region it is observed to occur in Oro Bay, Mambare Bay, near Busama Massava Bay, Pulie R., Kairiru I., Matanalauna R and Lihei R. It is also recently recorded by Munro (1958) from Papua, Australian New Guinea, New Hanover and Admiralty Is. The distribution of this species in the Indian waters is wide being found to occur both on the east and west coasts of the country; it occurs particularly in greater abundance on the north-western coastal regions from Bombay to Kutch.

PART - II

FOOD AND FEEDING HABITS

The importance of the study of food and feeding habits of a fish is well established, as it enables one to understand its behaviour in respect of its migration, growth and breeding. Some of the outstanding works in this field of investigation are of Johnstone (1907), Bullen (1912), Lebour (1919, '22 and '27), Hickling (1927), Frost (1943), Hynes (1950), Kow (1950), Jones (1954) and Longhurst (1957).

In regard to Polynemid fishes, Bal and Pradhan (1945) indicated the nature of the food of adult Eleutheronema tetradactylum. Mookerjee et al (1946) have determined the food of Polynemus sextarius. Chacko (1949) has described briefly the food of E. tetradactylum, P. indicus and P.heptadactylus. Bapat and Bal (1952) have mentioned the food of young E.tetradactylum and P.heptadactylus. Devanesan and Chidambaram (1953) have recorded the food of P.indicus. Malhotra (1953) has done an extensive study of the stomach contents of E.tetradactylum. Mohamed (1955) in his preliminary studies on Polydactylus indicus has commented on the food of smaller and larger fish and later Karekar and Bal (1958) have worked out the food and feeding habits of the same species in greater detail. The food and feeding habits in P.indicus have also been studied by Kuthalingam (1960) in connection with its life history.

It may also be mentioned here that the works of

Hornell and Nayudu (1923), Devenesan (1932), Job (1940), Chidambaram (1944), Vijayaraghavan (1951, 1953 a & b), Pillai (1952 & '53), Bhimachar and George (1952), Bal and Joshi (1956), Palekar and Bal (1959), Kuthalingam (1959 a) are some of the important ones on the food of fishes other than Polynemids of the Indian waters.

It is seen from the above that no attempt has been made so far to study in detail the food and feeding habits of Polynemus heptadactylus. The present study deals with the food of this fish in its juvenile and adult stages and the fluctuations in the component items of food in different months of the year.

Material and Methods

The material for this study consisted of 160 samples of P. heptadactylus, collected during the period April 1956 to March 1958 at two important fish landing places in Bombay viz. Sassoon Docks and Versova. On an average 7 samples per month, each consisting usually of 10 specimens, were examined. No sample for the month of September 1956 could be obtained due to unfair weather. The samples had a total of 1,648 specimens, of which 675 were collected during the period April 1956 to March 1957 and 973 from April 1957 to March 1958. Furcal length which is the distance between the tip of snout and the shortest caudal fin ray, is taken as a standard of measure throughout the present investigation. As the smallest maturing fish examined, measured 103 mm. in furcal length, all specimens measuring upto 105 mm were grouped as juveniles; above this length all were grouped as adults. Accordingly, the number of juveniles examined were 464 and adults 211 in the first year and 521 juveniles and 452 adults in the second year.

The fish when brought to the laboratory were measured for length and cut open; the sex and stage of maturity in females were noted. The fish with extroverted stomachs were sorted out and discarded. The identification of every food organism upto the species was not possible when digestion had far advanced. They were identified upto the species wherever possible and only upto the genus and family when identification could not be made further. The food of this species was analysed by Hynes's (1950) points method. Accordingly, by eye estimation the stomachs were allotted points in relation to their fullness, such as, full stomach (F) - 20, $\frac{3}{4}$ full - (3F/4) - 15, $\frac{1}{2}$ full (F/2) - 10, $\frac{1}{4}$ full (F/4) - 5 and traces (T) - 2 to 3. No fish with a gorged stomach was noticed during the study. Further, these points were distributed amongst individual food items according to the estimated volume. The points gained by one individual food item during a month were added up and divided by the number of fish examined to ascertain the average feeding activity for a particular item of food.

<u>Empty Stomachs</u>

During the course of this study empty stomachs appeared to occur in very high percentage, both amongst the juvenile and adult fish. In the first year of observation 201 juveniles amongst 464 examined forming 43%, 119 adults amongst 211 forming 56% and in the second year 233 juveniles amongst 521 forming 45%, 257 adults amongst 452 forming 57%, had their stomachs empty. It is seen that in both the years empty stomachs occurred in a higher proportion in adults than in juveniles, the difference being 13% in the first year and 12% in the second year. The high percentage of empty stomachs occurring in this species does not seem to be unusual as similar instances have been observed in most other fishes like Pomadasys juvelini, Drepane punctata and Trygon marginata by Longhurst (1957) and also in yellowfin tuna, Neothunnus macropterus by Alverson (1963). Amongst the trawler catches on the Indian coasts, empty or extroverted stomachs in Pseudosciaena diacanthus, Otolithoides ruber (Mohamed, loc.cit.) and Ilisha filigera (Meenakshisundaram and Marathe, 1963) have been on record.

The fluctuations in the percentage occurrence of empty stomachs were highly irregular from month to month in juveniles and adults in both the years. They neither showed any relationship to the season nor to the size of the fish. The monthly percentages of empty stomachs in the juveniles (Table 1) varied from 23 in December to 89 in August and October in the first year. The number of adult specimens examined during June and July 1956 and from January to March 1957 being too small they showed a wide range of none in March to hundred percent in July of empty stomachs in the first year. The monthly percentages of empty stomachs for the juveniles in the second year varied from 16 in November

Table 1.

Monthly percentage occurrence of empty stomachs in the juvenile and adult P. heptadactylus during April 1956 - March 1958.

Month	1956-'57				1957-'58			
	Juveniles		Adults		Juveniles		Adults	
	Fish examined	% of empty stomachs	Fish examined	% of empty stomachs	Fish examined	% of empty stomachs	Fish examined	% of empty stomachs
April	49	71	55	60	82	42	28	26
May	50	30	25	44	101	50	25	32
June	25	76	3	67	54	61	52	46
July	17	59	5	100	30	83	40	55
August	9	89	10	80	39	23	20	55
September	--	--	--	--	29	38	51	29
October	18	89	47	72	30	37	30	43
November	15	73	40	35	6	16	23	30
December	43	23	13	69	63	59	27	11
January	116	34	4	25	53	28	46	46
February	67	33	7	29	35	34	63	57
March	55	27	2	0	19	16	49	31

Table 2.

Percentage occurrence of stomachs in different degrees of fullness in juvenile and adult P. heptadactylus during 1956 - '58.

Year	Juveniles					Adults				
	F	3F/4	F/2	F/4	T	F	3F/4	F/2	F/4	T
1956-57	27	1	36	33	3	22	9	17	41	11
1957-58	25	1	27	46	1	20	1	27	51	1

1957 and March 1958 to 83 in July 1957 and those for adults from 11 in April and December 1957 to 57 in February 1958.

Feeding Activity

The food analysis of P. heptadactylus is based on 551 juveniles and 287 adults. Table 2 shows the percentages of different degrees of fullness of stomachs in juveniles and adults during the years 1956-57 and 1957-58. It is seen that amongst the juveniles, both the half-full and quarter-full stomachs occurred in good percentages while in adults, only the quarter-fulls. The percentages of full stomachs were more or less the same in both the years, being 27 and 25 for the juveniles and 22 and 20 for the adults.

To know if there is any seasonal variation in the degrees of fullness of stomachs, monthly analysis was attempted for juveniles and adults separately. It is seen that full stomachs were absent in the juveniles of the samples (Table 3) for the months April and June to October of the first year only; in the second year full stomachs appeared all through. The percentages of full stomachs ranged between 6 in May and 50 in November in the first year and 14 in May and June and 40 in August in the second year. Of the partially full stomachs, three-fourth-fulls appeared in April 1956 with 7% and in January of both the years with 3%; half-fulls had their monthly percentages ranging between 11 in May and 100 in August in the first year and between 17 in August and 40 in July in the

Table 3.

Monthly percentage occurrence of stomachs in different degrees of fullness in juvenile *P. heptadactylus* during April 1956 to March 1958.

Month	1956 - '57					1957 - '58				
	F	3F/4	F/2	F/4	T	F	3F/4	F/2	F/4	T
April	-	7	43	50	-	33	-	25	42	-
May	6	-	11	83	-	14	-	22	64	-
June	-	-	17	83	-	14	-	38	48	-
July	-	-	71	29	-	20	-	40	40	-
August	-	-	100	-	-	40	-	17	43	-
September	--	--	--	--	--	28	-	22	50	-
October	-	-	-	100	-	16	-	26	58	-
November	50	-	25	25	-	20	-	-	80	-
December	36	-	40	18	6	15	-	27	58	-
January	45	3	35	16	1	29	3	37	31	-
February	42	-	33	25	-	30	-	35	35	-
March	12	-	55	33	-	37	-	44	13	6

second year; quarter-fulls showed their monthly percentages fluctuating between 16 in January and 100 in October of the first year and 13 in March and 80 in November of the second year; and traces occurred rarely in some of the months. The hundred percent half-full stomachs in August and quarter-fulls in October 1956 was when the numbers of juveniles examined were very few, being 1 and 2 in the respective months.

Amongst the adults, full stomachs were not encountered (Table 4) during May, July and August of the first year and June of the second year. The monthly percentages of the full stomachs ranged between 9 in April and 100 in June and January in the first year and between 9 in February and March, and 57 in October in the second year. In June and January of the first year the numbers of adults with food in the samples were only 1 and 3 respectively. Three-fourth-full stomachs showed the percentage range of 5 in April to 50 in August in the first year and 4 in September and March to 15 in October in the second; half-full stomachs had their percentages ranging between 14 in April-May and 40 in February of the first year and from 8 in July and 55 in March of the second year; quarter-fulls had their monthly percentages fluctuating between 20 in February and 64 in May in the first year and 14 in October and 75 in July in the second; traces occurred occassionally.

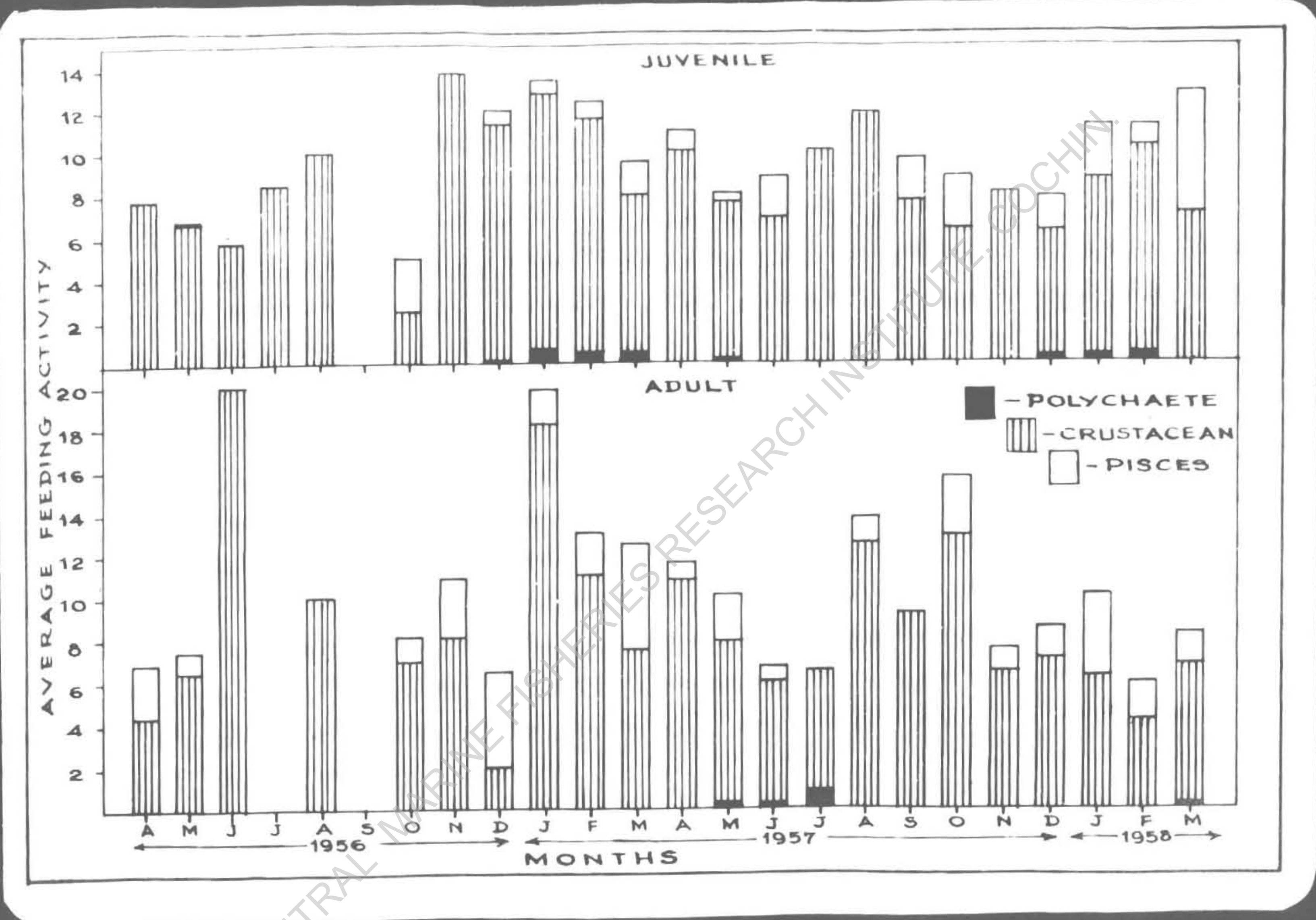
Though the percentages of full stomachs increased slightly during certain months, no definite period can be

Table 4.

Monthly percentage occurrence of stomachs in different degrees of fullness in adult P. heptadactylus during April 1956 - March 1958.

Month	1956 - '57					1957 - '58				
	F	3F/4	F/2	F/4	T	F	3F/4	F/2	F/4	T
April	9	5	14	45	27	35	-	30	35	-
May	-	22	14	64	-	31	-	25	44	--
June	100	-	-	-	-	–	-	40	60	-
July	-	-	-	-	-	17	-	8	75	-
August	-	50	-	50	-	50	-	20	20	-
September	--	--	--	--	--	17	4	31	48	-
October	16	-	23	46	16	57	15	14	14	-
November	31	7	31	31	-	13	-	13	74	-
December	25	-	-	-	75	21	-	11	68	-
January	100	-	-	-	-	36	-	-	64	-
February	40	-	40	20	-	9	-	26	60	5
March	50	-	-	50	-	9	4	55	32	-

3. Monthly food composition of juvenile and adult *P. heptadactylus*.


JUVENILE
ADULT
AVERAGE FEEDING ACTIVITY
- POLYCHAETE
- CRUSTACEAN
- PISCES
A M J J A S O N D J F M A M J J A S O N D J F M
1956
1957
1958
MONTHS

indicated when either the juveniles or the adults fed actively. This is further supported by the wide fluctuation in the percentages of different degrees of fullness of stomachs, irrespective of the months in which they occurred.

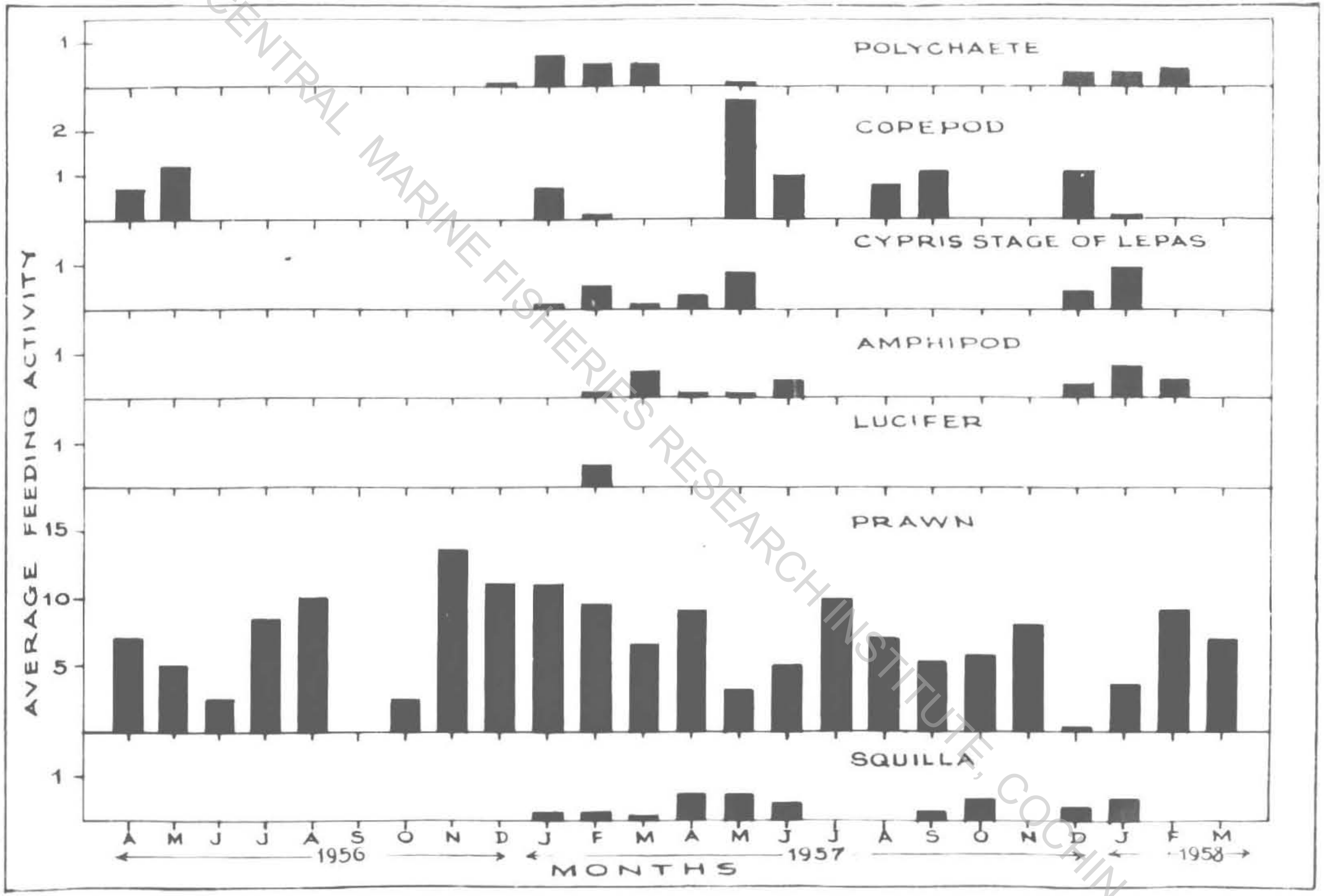
Composition of Food

The composition of food of *P. heptadactylus* in both the juveniles and adults is presented in Fig. 3 and it is observed that crustaceans dominated throughout forming the major food item. This item was not noticed in the food of adults in July 1956. Its average feeding activity ranged from 2.5 in October 1956 to 13.7 in November 1956 for juveniles and from 2.0 in December 1956 to 20.0 in June 1956 for adults.

Next to crustaceans came the pisces and polychaetes in the order of abundance. Pisces were not encountered in the food of juveniles during April, June to August and November 1956 and also in July, August and November 1957. The average feeding activity on this group varied from 0.1 in May 1956 to 5.8 in March 1958 for the juveniles. This food was absent in adults from June to August 1956 and July as well as September 1957. The average feeding activity on this varied from 0.7 in June 1957 to 5.0 in March 1957 for adults.

Polychaetes appeared in December 1956, January to March, May and December 1957 as well as in January and February 1958 in the food of the juveniles. The average feeding activity on this item ranged between 0.1 in December 1956 and May 1957

4. Monthly distribution of polychaete and crustacean food items in the stomachs of juvenile *P. heptadactylus*.


POLYCHAETE
COPEPOD
CYPRIS STAGE OF LEPAS
AMPHIPOD
LUCIFER
PRAWN
SQUILLA
AVERAGE FEEDING ACTIVITY
A M J J A S O N D J F M A M J J A S O N D J F M
1956
1957
1958
MONTHS

and 0.7 in January 1957. In the food of adults it appeared during May to July 1957 and March 1958 with the average feeding activity ranging between 0.1 in March 1958 and 0.8 in July 1957.

Sometimes molluscs and echinoderms were also noticed in the food of this fish. Occassionally, sand and mud were found in the stomachs of adults.

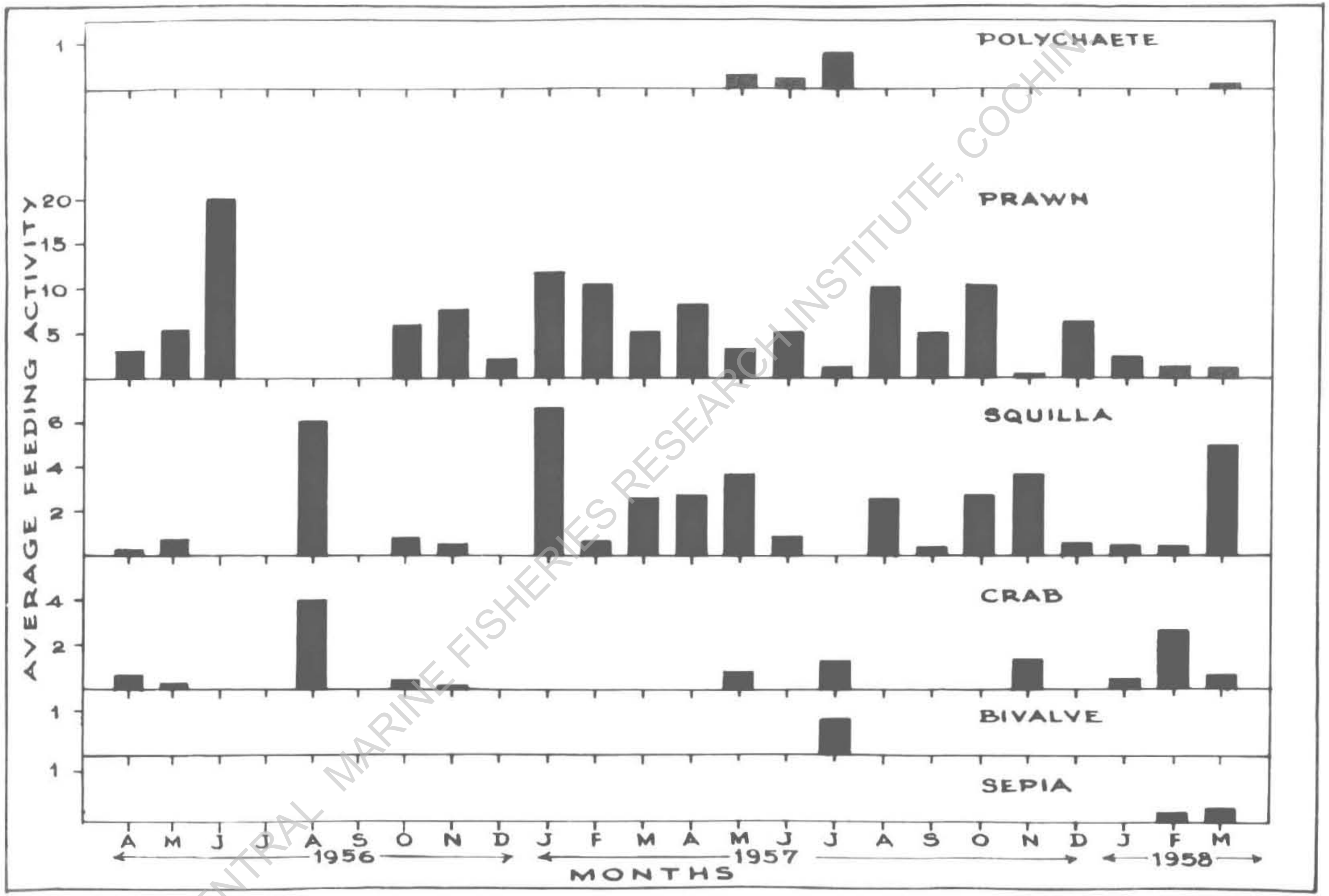
The monthly distribution of different items of food in juveniles and adults is given in the following account.

Crustaceans

The crustacean food of juveniles mainly consisted of planktonic forms like copepods, cypris stage of lepas, amphipods and other crustaceans as small prawns and stomatopoda. Penaeid and carid prawns, stomatopoda and brachyura comprised the food of adults. Often crustacean appendages alone were noticed in the stomach of this fish.

Prawns:- Amongst the crustaceans, prawns (Figs. 4 & 5) ranked very high in the food of this fish throughout its life. They formed the food of juveniles during all the months. In the case of juveniles, the lowest average feeding activity of 0.3 was in December 1957, while the highest of 13.7 was in November 1956. For adults the minimum average feeding activity of 0.3 and the maximum of 20 were during November 1957 and June 1956 respectively. The stomach contents of juveniles revealed *Acetes indicus* and of adults in addition to this, *Parapenaeopsis sculptilis*, *Hippolysmata ensirostris* and *Palaemon tenuipes*.

5. Monthly distribution of polychaete, crustacean and molluscan food items in the stomachs of adult *P. heptadactylus*.


POLYCHAETE
PRAWN
SQUILLA
CRAB
BIVALVE
SEPIA
AVERAGE FEEDING ACTIVITY
1
20
15
10
5
6
4
2
4
2
1
1
A M J J A S O N D J F M A M J J A S O N D J F M
1956
1957
1958
MONTHS

<u>Squilla spp.</u>:- Next to prawns <u>Squilla</u> spp. (Figs 4 & 5) representing stomatopoda ranked second amongst the crustacean food. This item appeared in the food of juveniles from January to June 1957, September, October and December 1957 and also in January 1958. The minimum average feeding activity of 0.1 in juveniles was in March 1957 and the maximum of 0.6 was in April-May 1957. It occurred in the stomachs of adults throughout excepting in the months of June, July and December 1956 and also July 1957. The minimum average feeding activity of 0.2 in adults was in April 1956 and the maximum of 6.6 was in January 1957.

<u>Crab</u>:- As a member of brachyura (Fig. 5), this item was found in the stomachs of adults only and ranked third amongst crustaceans in the order of abundance. It occurred in the months of April, May, August, October and November of 1956 May, July and November of 1957 and from January to March of 1958. The minimum average feeding activity of 0.1 was noticed during November 1956 and the maximum of 4.0 during August of the same year.

<u>Copepods</u>:- Of the planktonic food items found in juveniles, copepods (Fig. 4) occupied the first place. This food item was noticed in April and May 1956, January, February, May, June, August, September and December 1957 and also in January 1958. The minimum average feeding activity of 0.1 was in February 1957 and January 1958 while the maximum of 2.7 was in May 1957. Copepods noticed in the food were the calanoid, cyclopoid and harpacticoid forms.

Cypris stage of Lepas:- It occurred in the food of juveniles (Fig. 4) only from January to May and December 1957 and also in January 1958. The minimum average feeding activity of 0.1 was observed in January and March 1957, the maximum of 0.9 being in January 1958.

Amphipods:- This food item occurred in the food of juveniles (Fig.4) only. It was noticed from February to June 1957 and from December 1957 to February 1958. The minimum average feeding activity of 0.1 was seen in February, April and May 1957 and the maximum of 0.7 in January 1958.

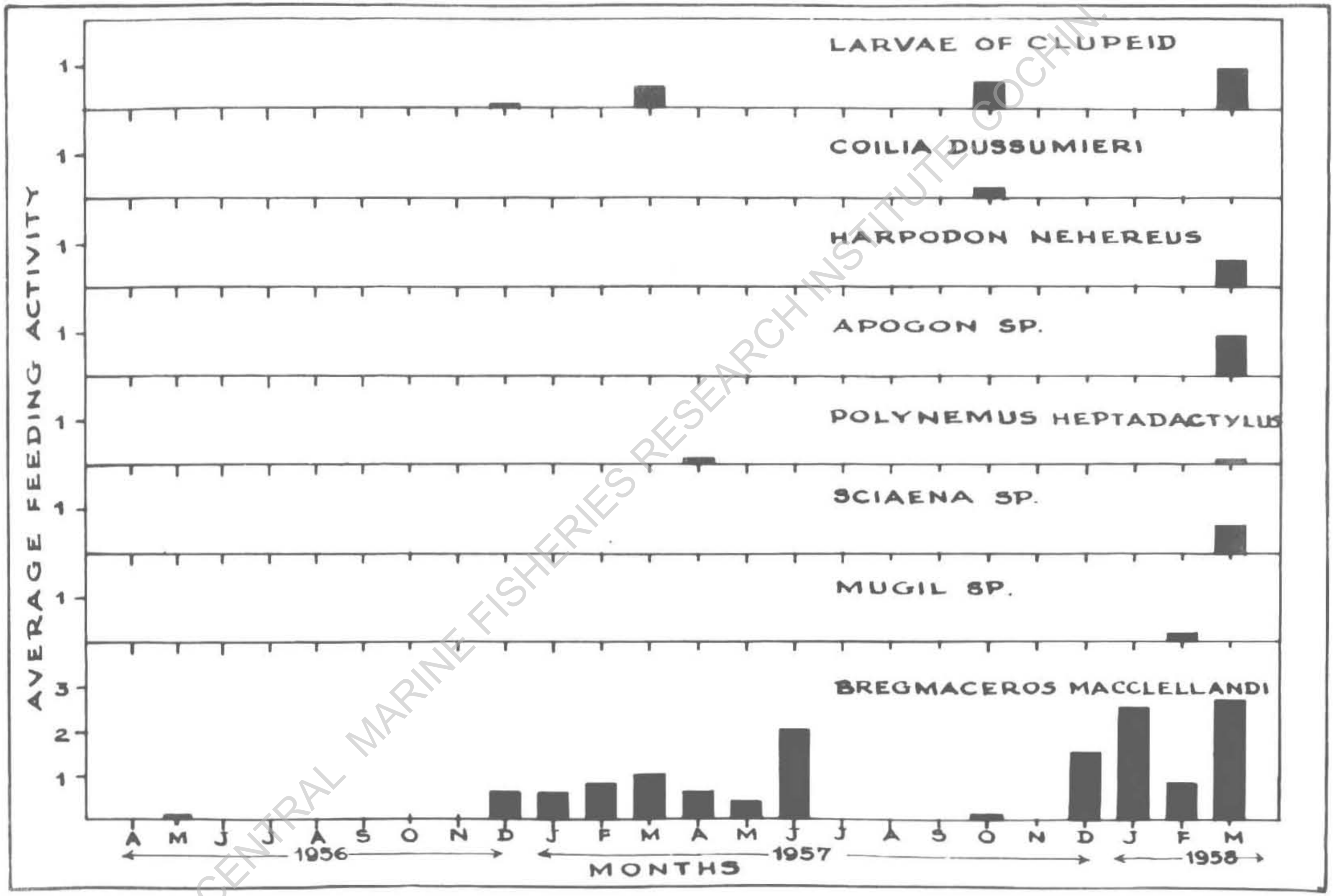
Lucifer:- It appeared in the food of juveniles (Fig. 4) only, in the month of February 1957, with an average feeding activity of 0.5.

P i s c e s

Altogether 11 species of bony fishes occurred in the food of *P. heptadactylus*. Of these, clupeid larvae, *Bregmaceros mcClellandi*, *Coilia dussumieri*, *Harpodon nehereus* and *Sciaena* spp. were common in both the juvenies and adults. *Apogon* spp., *P. heptadactylus* and *Mugil* spp. were found occurring only in juveniles and *Trichiurus* spp., *Periopthalmus* spp. and *Cynoglossus* spp. in adults.

In the fish food of juveniles, clupeid larvae and *B. mcClellandi* were the most common and the rest rare. In the adults, *B. mcClellandi*, *Periopthalmus* spp., *Trichiurus* spp. and Sciaena spp. were the most common and the rest rare.

6. Monthly distribution of fish food items in the stomachs of juvenile *P. heptadactylus*.



LARVAE OF CLUPEID
COILIA DUSSUMIERI
HARPODON NEHEREUS
APOGON SP.
POLYNEMUS HEPTADACTYLUS
SCIAENA SP.
MUGIL SP.
BREGMACEROS MACCLELLANDI
AVERAGE FEEDING ACTIVITY
1
2
3
A M J J A S O N D J F M A M J J A S O N D J F M
1956
1957
1958
MONTHS

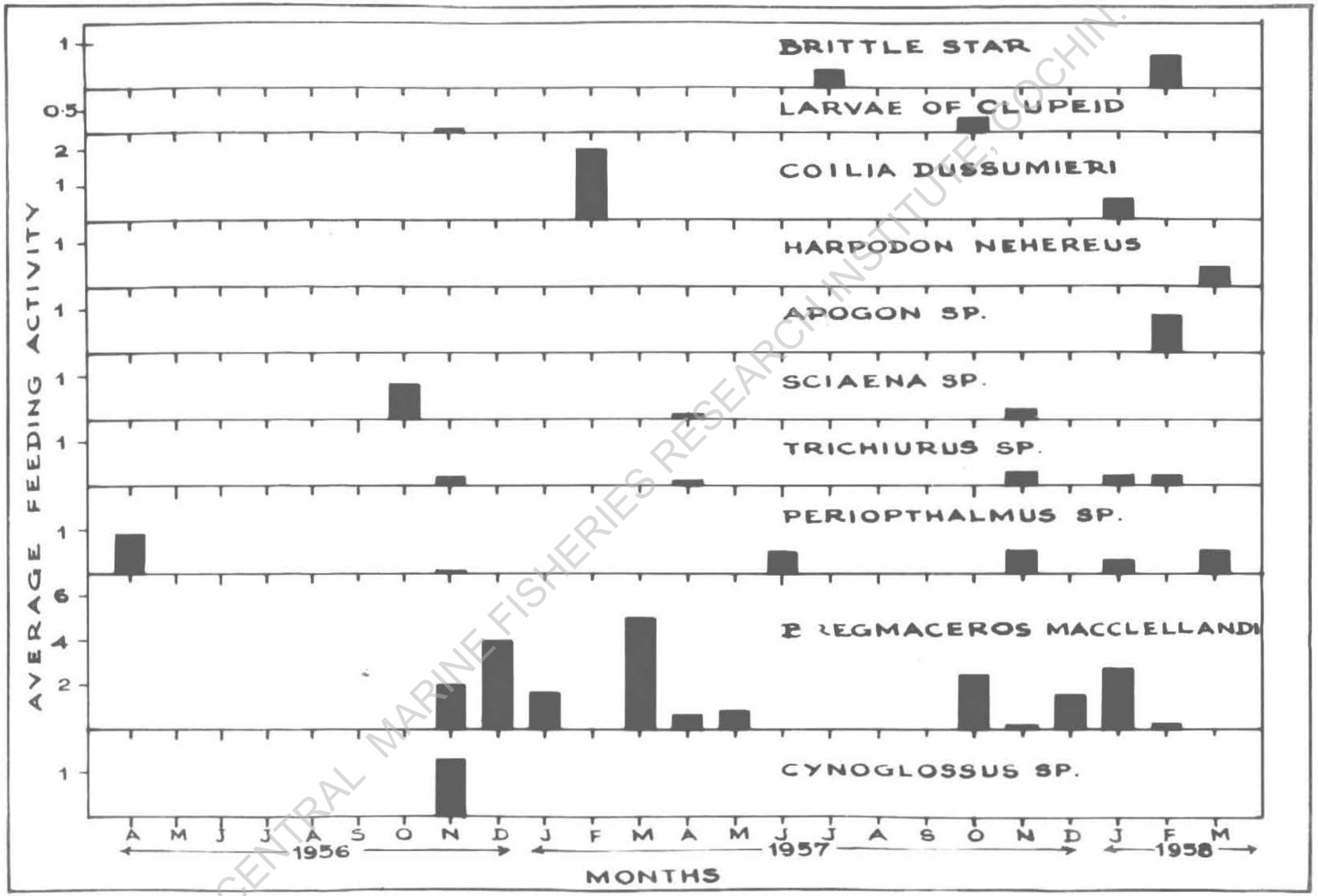
B. mcClellandi:- This ranked first (Figs. 6 & 7) in the food of both the juveniles and adults and occurred in the months of May and December 1956, January to June, October and December 1957 and January to March 1958 in the food of juveniles. It appeared in adults in November and December 1956, January, March to May and October to December 1957 and also in January and February 1958. Both for juveniles and adults, the minimum average feeding activity found was 0.1, being in May 1956 and October 1957 for the former and November 1957 for the latter. The maximum of 2.7 in juveniles and 5.0 in adults were in the month March of 1958 and 1957 respectively.

Clupeid larvae:- In juveniles (Fig. 6) this food item occurred in December 1956, March and October 1957 and March 1958 and in adults (Fig.7) it appeared in November 1956 and October 1957. The maximum average feeding activity for juveniles was 0.9 in March 1958 and for adults 0.3 in October 1957.

Periopthalmus spp.:- This food was found in the stomachs of adults (Fig. 7) only in the months of April and November 1956, June and November 1957 as well as January and March 1958. The minimum average feeding activity of 0.1 and the maximum of 0.9 were in the months November and April 1956 respectively.

Trichiurus spp.:- This was encountered in the food of adults (Fig. 7) in November 1956, April and November 1957 and January and February 1958. The maximum average feeding activity of 0.3 and the minimum of 0.1 were found in November and April 1957

7. Monthly distribution of echinoderm and fish food items in the stomachs of adult P. *hexadactylus*.


BRITTLE STAR
LARVAE OF CLUPEID
COILIA DUSSUMIERI
HARPODON NEHEREUS
APOGON SP.
SCIAENA SP.
TRICHIURUS SP.
PERIOPTHALMUS SP.
BREGMACEROS MACCLELLANDI
CYNOGLOSSUS SP.
AVERAGE FEEDING ACTIVITY
A M J J A S O N D J F M A M J J A S O N D J F M
1956
1957
1958
MONTHS

respectively.

Sciaena spp.:- The stomach contents of adults (Fig.7) had this food item in October 1956 and April and November 1957. The maximum average feeding activity of 0.8 was recorded in October 1956.

In regard to the fishes occurring rarely in the food of juveniles, C.dussumieri occurred in October 1957, H.nehereus, Apogon spp. and Sciaena spp. were recorded in March 1958; P.heptadactylus appeared in April 1957 and March 1958 while Mugil spp. in February 1958. Fishes of rare occurrence in adults were C.dussumieri in February 1957 and January 1958, H.nehereus in March 1958 and Cynoglossus spp. in November 1956.

Pøolychaetes

Polychaetes (Figs. 3, 4 & 5) were found in the food of both the juveniles and adults. Their frequency of occurrence and also the rate of feeding in juveniles and adults, have been discussed earlier.

Molluscs

Molluscs were poorly represented in the food of P.heptadactylus by bivalves and sepia.

Bivalves:- Bivalves (Fig. 5) appeared only in July 1957, in the food of adults giving an average feeding activity of 0.8.

Cephalopods:- Sepia (Fig.5) appeared in the food of adults during February and March 1958, giving an average feeding activity 0.2 and 0.3 respectively.

E c h i n o d e r m s

The order Ophiuroidea alone was represented in the food of adults.

Brittle star:- These were noticed in the stomachs of adults (Fig. 7) during July 1957 and February 1958 with an average feeding activity of 0.4 and 0.7 respectively.

Conclusion:- Seasonal variation in temperature or other factors in the environments may affect the feeding rate of a fish. Longhurst (loc.cit.) states that Todd (1915) had found 90% of empty stomachs in North Sea plaice during winter against only 1% - 2% in summer. Occurrence of empty stomachs in fishes cannot be attributed to the temperature variation in tropical waters where the range is too small. Drop in salinity due to influx of fresh water after rain, strong currents, disturbance of waters by powerful winds etc. during monsoon months may adversely affect the feeding rate of fish. However, in *P. heptadactylus* the feeding rate does not seem to have retarded in the monsoon months of June to September. The high percentage of empty stomachs found almost throughout the year shows no relationship with any of the changing environmental factors.

Hertling (1938) as cited by Longhurst (loc.cit.) states that species in which fish forms an important item of food tend to have a high proportion of empty stomachs, the main reason for it being that the calorific value of fish is ~~weight~~ for weight higher than other items like the crustaceans. The daily intake of ichthyophagous species can be lower and discontinuous than those whose diet consists chiefly of benthic invertebrates. Longhurst (loc.cit.) is of the opinion that the high percentage of empty stomachs is due to differential disgorging. He opines that in species with a mixed diet the smaller ones become more crushed in the trawl and so more frequently disgorge; and the ichthyophagous ones may "disgorge their single, large food masses more completely than if their stomachs contained many smaller organisms of which some could remain behind and so be recorded".

Alverson (1963) has noticed the percentage of empty stomachs in yellowfin and skipjack tunas varying considerably from area to area. He has been able to correlate a positive relationship between the percentage of empty stomachs in an area and the percentage of total volume that is made up of fish in that area for the yellowfin tuna alone and not for skipjack. He also considers that the exoskeleton of the crustaceans is digested at a slower rate than fish and remains in the stomach for a longer time, thus reducing the percentage of empty stomachs. In spite of the crustaceans ranking high in the food of juveniles and adults, the percentage of empty stomachs found in them has been very high in *P.heptadactylus*.

P.heptadactylus is a carnivorous fish with a mixed diet of crustaceans ranking first, followed by pisces, polychaetes, molluscs and echinoderms. The food of juveniles consists of planktonic forms, other crustaceans, fishes and polychaetes whereas that of adults all other items excepting the planktonic forms. In the juveniles amongst the planktonic forms, copepods dominated, amongst the crustaceans small prawns like *Acetes indicus* and *Squilla* spp. and amongst pisces *B.mcClellandi*. Amongst the crustacean food in the adults, Penaeid and Carid prawns dominated and were followed by *Squilla* spp. and crabs and amongst pisces just as in the case of juveniles by *B.mcClellandi*. The food composition of the juveniles and adults did not show appreciable variation. The total absence of planktonic forms and the presence in large quantities of benthic forms in the food of adults in contrast with the food of the juveniles, is apparently due to the reason that the former prefer mostly benthic habitats and the latter more of surface waters.

Karekar and Bal (loc.cit.) have observed low feeding activity in *P.indicus* prior to spawning and high after spawning. However, the feeding intensity in *P.heptadactylus* varied widely in both juveniles and adults but showed no significant fluctuations with reference to the breeding of this fish.

AGE AND GROWTH

For the proper management of fishery, a knowledge of the age composition of a population and the rate of growth of the species is of prime importance. The assessment of the age of a fish is also essential in solving many biological problems like longevity, rate of growth, age at maturity, spawning time etc. Three methods are generally used in the determination of age and growth of a fish, namely, a direct method of tagging and releasing the fish for subsequent recovery and two indirect methods, Peterson's method of length frequency distribution and the study of growth checks on the hard parts like otoliths, scales, opercular bones etc. The direct method of tagging is practicable in very long range studies only.

Age determination and growth studies based eitherr on the length frequency or growth checks marked on otoliths or on scales in the California sardine, *Sardina caerulea* by Clark (1931), in the Starry flounder, *Platichthys stellatus* by Orcutt (1950), in the Dover sole, *Microstomus pacificus* by Hagerman (1952), in the Cabezon, *Scorpaenichthys marmoratus* by (O'Connell (1953), and in the anchoveta, *Cetengraulis mysticetus* by Bayliff (1964) are some of the outstanding contributions to this aspect of biology.

The findings of Chidambaram (1950) on *Sardinella longiceps*, of Sekharan on *Rastrelliger canagurta* (1958) and *Sardinella* spp., (1955, '59) of Bapat *et al* (1952) on *Harpodon nehereus*, of Seshappa and Bhimachar (1955) on

Cynoglossus semifasciatus and of Rao (1961) on Pseudosciaena diacanthus are important contributions to the knowledge of age and growth of some Indian marine fishes. Mention may also be made here to the brief account on the age and age composition of commercial catches of Polydactylus indicus in the trawler landings by Nayak (1959d). In the present study the indirect methods have been employed to determine the age and growth of Polynemus heptadactylus.

Material and Methods

This study is based on 22,292 P.heptadactylus landed by two types of gears, 'Dol' or the bag net and trawl nets during a period of three and a half years from January 1956 to May 1959. From the 'Dôl' altogether 126 samples totalling 12,128 fish were collected for 34 months during this period. On an average 4 samples, each consisting of about 100 fish, were measured every month. From the trawlers 84 samples with an average of 120 each totalling 10,164 fish were collected for 32 months during the same period.

As stated earlier, throughout these studies, the furcal length of the fish has been adopted instead of the total length because in the commercial catches some of the larger caudal fin rays are usually found damaged.

Otoliths and scales of 765 fish obtained from both the gears were removed. Sagitta, which is the biggest otolith in the fishes, can easily be removed from P.heptadactylus. The operculii and gills were removed first and then applying slight pressure with a pair of forcep in between the basioccipital and parasphenoid bones, the otoliths were exposed. They were cleaned in water, dried and kept in small covers noting the locality, length and sex of the fish from which they were taken. Scales were removed from the lateral body-wall lying beneath the distal end of the pectoral fin. After cleaning in water and drying, they were kept along with the otoliths.

Structure of Otoliths and Scales

Each otolith is slightly concave on the outer surface and is placed length-wise in the otic cavity. In the middle region of the concave surface is a small but a prominent nucleus. The growth is said to centre round this nucleus. On the inner convex surface of the otolith there is a deep groove running obliquely and serving as a passage to the branches of otic nerve and blood vessels. The edges are irregularly dented. The necessity of any clearing agent or mounting medium was not felt here. The otoliths were examined in water and the alternate opaque and translucent rings were clearly seen under the binocular microscope. The largest otolith measuring 11 mm in length was obtained from a fish 255 mm long.

The scale is ctenoid. The nucleus is situated at the anterior toothed portion which is embedded in the skin fold. Its posterior exposed border has three notches, the central one being more steep. There are usually three radii, each proceeding from the nucleus outwardly towards the three notches. Occasionally a fourth radius is also seen. As in otoliths, no special clearing agent or mounting medium was used in the examination of scales. The largest scale measuring 10 mm in length was obtained from a fish of 255 mm. In order to avoid any kind of bias, data on otoliths and scales were treated separately.

The Relation between Otolith-length and Scale-length with Fish-length

The relations between otolith-length and scale-length with fish-length have been established by various workers and they have been found to differ from fish to fish. Fairbridge (1951) states that with regard to the scales the problem becomes a bit complicated because till the fish reaches certain length the scales do not develop; all scales do not develop simultaneously, and their subsequent growth in proportion to the fish is also different in different parts of the body. To some extent the study of otoliths is simpler.

To avoid errors due to different growth rates in the scales in different parts of the body, scales for the study were selected from one definite place only i.e. on the lateral body-wall lying beneath the distal end of the pectoral fin. Fish-lengths were grouped into 15 mm class intervals. Fish-lengths, otolith-lengths and scale-lengths were recorded and shown graphically.

8. Relation between (a) otolith-length and fish-length,

(b) scale-length and fish-length in *P. heptadactylus.*

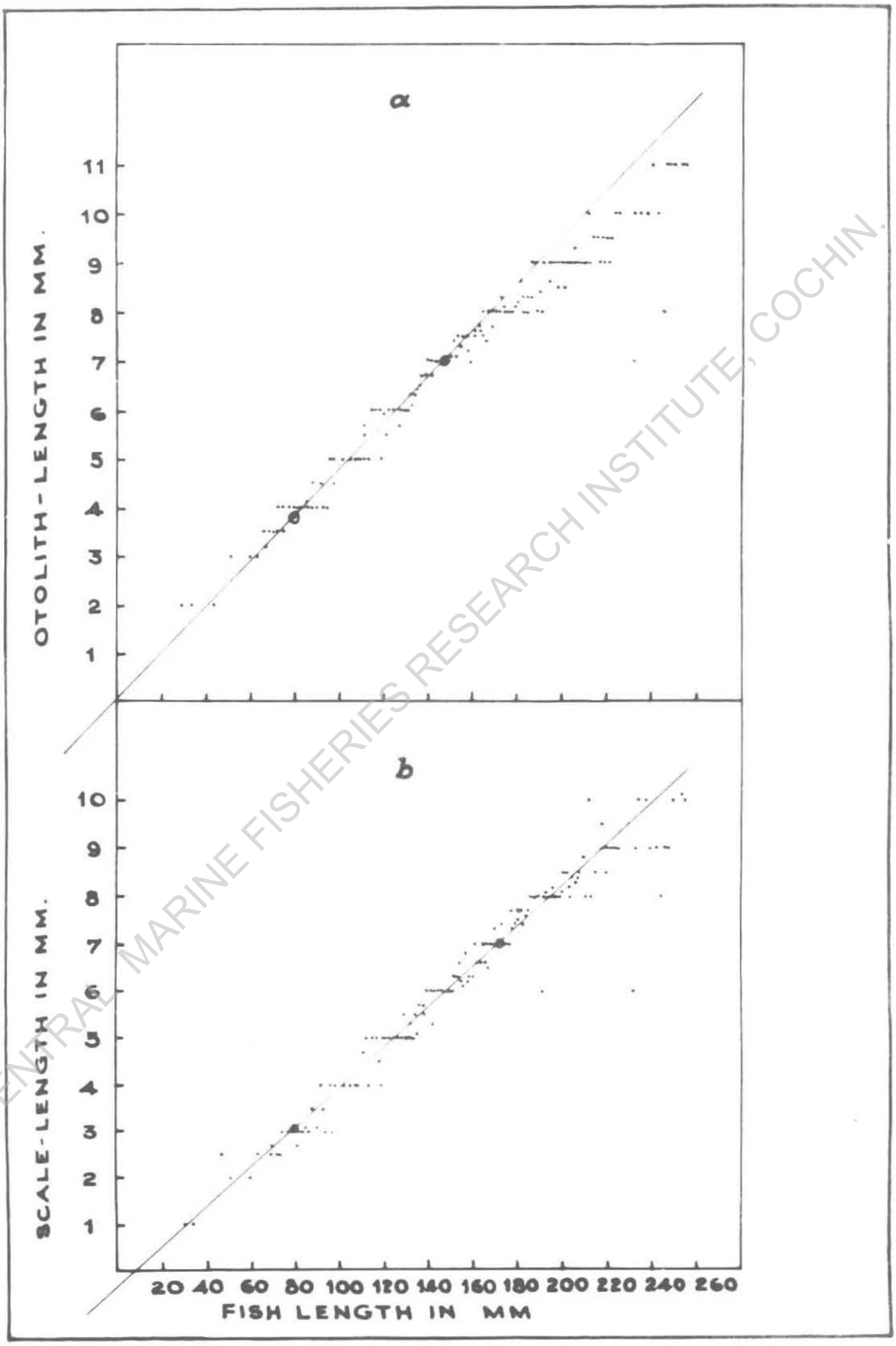

a
OTOLITH - LENGTH IN MM.
1
2
3
4
5
6
7
8
9
10
11
b
SCALE-LENGTH IN MM.
1
2
3
4
5
6
7
8
9
10
20 40 60 80 100 120 140 160 180 200 220 240 260
FISH LENGTH IN MM

Fig. 8a shows the relation between otolith-length and fish-length. It is seen that a straight line can be fitted closely to the points, and this has been done by the method of least squares (Snedecor, 1940). The regression co-efficients have been estimated in order to calculate the length of an otolith for a known fish-length and vice versa as shown below:

$y = a + bx$ is the equation for a straight line where y = fish-length, x = otolith-length and 'a' and 'b' are constants. The value of 'b' is computed from the normal equation -

$$b = \frac{\Sigma xy - \frac{(\Sigma x)\ (\Sigma y)}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}$$ and then 'a' from

$$a = \bar{y} - b\bar{x} \quad \text{where } \bar{y} = \frac{\Sigma y}{n} \quad \text{and } \bar{x} = \frac{\Sigma x}{n}.$$

By substituting the values of 'a' and 'b', the equation

$y = a + bx$ can be rewritten as

$y = -0.07 + 21.05\ x.$

The value of the constant 'a' in the equation being negative it is seen that the regression line when extrapolated cuts the fish-length axis at a negative otolith-length value of 0.07. Fairbridge (loc.cit.) who also found a similar case in the flat-head (Neoplatycephalus macrodon) otolith says, "If extrapolated, the regression lines would cut the fish-length axis at a negative otolith value". This he considers as absurd, and presumes that there is, in the very small flat-head, disproportionately faster growth of the otolith.

Further, it is observed from the Fig. 8a that in the early part of life till the fish reaches 80 mm in length, the otoliths seem to have faster linear growth as the observed values lie towards the otolith axis. Later on the growth relationship is in direct proportion till the fish is about 160 mm in length, as the values are seen to lie on the regression line. In the case of lengths beyond this, the observed values for otoliths are seen to lie towards the fish-length axis, thereby indicating that the fresh deposition of calcium carbonate is towards the thickness of the otolith rather than its length.

Fig. 8b shows the relation between the scale-length and the fish-length. A straight line has been fitted again by the method of least squares. The regression coefficients have been estimated. The scale-length and fish-length relationship is best fitted by the equation:

$$y = 9.87 + 22.97\,x$$

where 'y' = Fish-length, and
'x' = Scale-length.

The value of constant 'a' in the equation is positive and it is seen in the figure that the regression line cuts the fish-length axis at a length of 9.87 mm. This suggests that the scales on the lateral body-wall, beneath the distal end of the pectoral fin begin to develop first when the fish is about 10 mm in furcal length.

In this connection the work of Blackburn (1949) on the Australian pilchard (Sardinops neopilchardus) may be cited. He has found that when the regression line is extrapolated it cuts the fish-length axis at 15 mm, indicating thereby the formation of scales when the fish is of an average length of 15 mm. But from his practical experience he has noted that no fish less than 30 mm has any scale, all fish of 40 mm and more have at least some and at 32 mm the scaled and scaleless specimens are almost equal in number. Thus he concludes that the average length of pilchard at which the scales first appear is probably 32 mm. Moreover, he has also found that after its formation, the scale for a short time grows much faster than the fish after which their increments maintain a constant ratio.

Orcutt (loc.cit.) supporting other workers observations states, "actually the scales do not appear until after the fish has attained some length, but it is now generally believed that, once formed, the scales grow relatively faster than the fish for a short time after which the rates of growth of both become practically equal". Considering the variations occurring in this relationship very early or late in the life of a fish, he suggests to omit corrections of equations for these slight differences because usually the fishery is sustained by the fish at the ages when the scale and body growth rates are almost equal.

The smallest P. heptadactylus examined during the course of this study was 15 mm in length when the scales were already seen to have developed on its body. Since specimens smaller than 15 mm could not be collected, it is not possible to judge if there existed any difference in growth of scales in different specimens of this species below 15 mm as was found by Blackburn (loc.cit.) in the case of pilchard. From the Fig. 8b it can be seen that in the case of P.heptadactylus almost all the values for scale-length, lie on the calculated straight line indicating thereby, that the ratio maintained between the scale-length and fish-length, is constant; however, the relationship between the length of otolith and fish-length differs considerably in the higher length groups. Thus Orcutt's (loc.cit.) suggestion to omit corrections for the slight differences at different ages to the length of the otoliths in relation to the lengths of the fish can be accepted because these higher length groups contribute only to an insignificant proportion of the commercial catches.

Rings on Otoliths and Scales

Most of the juveniles above 26 mm in length show a ring on their otoliths, 25 fish ranging from 22 mm to 30 mm were examined to see whether the otoliths had any ring. It is found that a faint ring around the nucleus makes its appearance when the fish is about 23 mm. This ring remains in faint condition till the fish reaches about 26 mm. When the fish grows to the size of 27 mm, it is found that about 67% of them clearly show one ring each on their otoliths. The percentage of occurrence of rings on otoliths of fish above 27 mm in length is always 100.

Gottlieb (1956)* in his work on age and growth of the red mullet of Mediterranean waters has come across a similar ring which he refers to as 'larval-ring'. The cause for the formation of this ring, he attributes to the change in the habitat from pelagic to demersal where the temperature of water is low.

To find whether such a change in habitat occurs in this fish also, food of these smaller fish was analysed, but no variation in the food composition was noticed from that of other juveniles. Secondly, fish below 23 mm were found to occur along with the larger fishes in the 'Dol' net catches from inshore waters. Hence, the formation of this ring cannot be attributed to the change of habitat alone. Undoubtedly, there must be some unfavourable condition, not known so far, for the formation of this ring.

In the case of scales, no ring corresponding to the larval-ring of otoliths was noticed. The first ring was noticed on the scales of fish 83 mm long as seen in Table 5.

The number of rings observed on otoliths varies from 1 to 5 (Fig. 9). Table 6 shows the ring distribution in percentage at each 15 mm class intervals. The larval-ring alone is seen till the size of 68 mm; the second ring is seen at 83 mm; the third, fourth and fifth rings are seen at 128 mm, 158 mm and 188 mm respectively. These measures indicate the mid-point values of the corresponding size-groups.

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* The age and growth of the red mullet *Mullus barbatus* L. in Israel waters 1953-55. *Sea Fish Res. Stat.* *Bull* No. *12*:3-20.

8. Growth checks on otoliths of
P. heptadactylus

a) with larval ring from a fish measuring 40 mm in length x 5

b) with two rings from a fish of 95 mm in length x 5

c) with three rings from a fish of 144 mm in length x 5

d) with four rings from a fish of [illegible] mm in length x 5

e) with five rings from a fish of 240 mm in length x 5

Table 5

Percentage frequencies of rings on the Scales of

P. heptadactylus at each of 15 mm length groups

Size-group (mid-point mm.)	Fish examined	% of fish with scale rings
23	16	0
38	15	0
53	3	0
68	14	0
83	24	4
98	7	29
113	20	45
128	77	34
143	109	54
158	141	77
173	138	75
188	105	93
203	56	98
218	22	91
233	10	100
248	8	100

Table 6

Percentage frequencies of number of rings on the Otoliths of *P. heptadactylus* at each of 15 mm. length-groups.

Size-group (Mid-point mm.)	Fish examined	Number of rings on the Otoliths				
		1	2	3	4	5
23	16	100	-	-	-	-
38	15	100	-	--	-	-
53	3	100	-	-	-	-
68	14	100	-	-	-	-
83	24	83	17	-	-	-
98	7	57	43	-	-	-
113	20	25	75	-	-	-
128	77	14	75	11	-	-
143	109	13	65	22	-	-
158	141	1	43	50	6	-
173	138	1	25	66	8	-
188	105	-	10	71	18	1
203	56	-	2	59	37	2
218	22	-	-	50	45	5
233	10	--	10	40	40	10
248	8	-	-	12	63	25

765

Table 7

Percentage frequencies of number of rings on the Scales of *P. heptadactylus* at each of 15 mm length-groups.

Size-groups (Mid-point mm.)	Fish examined	Number of rings on the Scales 1	2	3	4
23	-	-	-	-	-
38	-	-	-	-	-
53	-	-	-	-	-
68	-	-	-	-	-
83	1	100	-	-	-
98	2	100	-	-	-
113	9	100	-	-	-
128	26	88	12	-	-
143	59	75	25	-	-
158	109	46	50	4	-
173	103	14	81	5	-
188	98	5	50	44	1
203	55	7	33	55	5
218	20	-	50	45	5
233	10	10	30	50	10
248	8	-	50	25	25

H 97

10. Growth checks on scales of _P. heptadactylus_

a) with one ring from a fish of
96 mm in length x 5

b) with two rings from a fish of
138 mm in length x 5

c) with three rings from a fish of
152 mm in length x 5

d) with four rings from a fish of
230 mm in length x 5

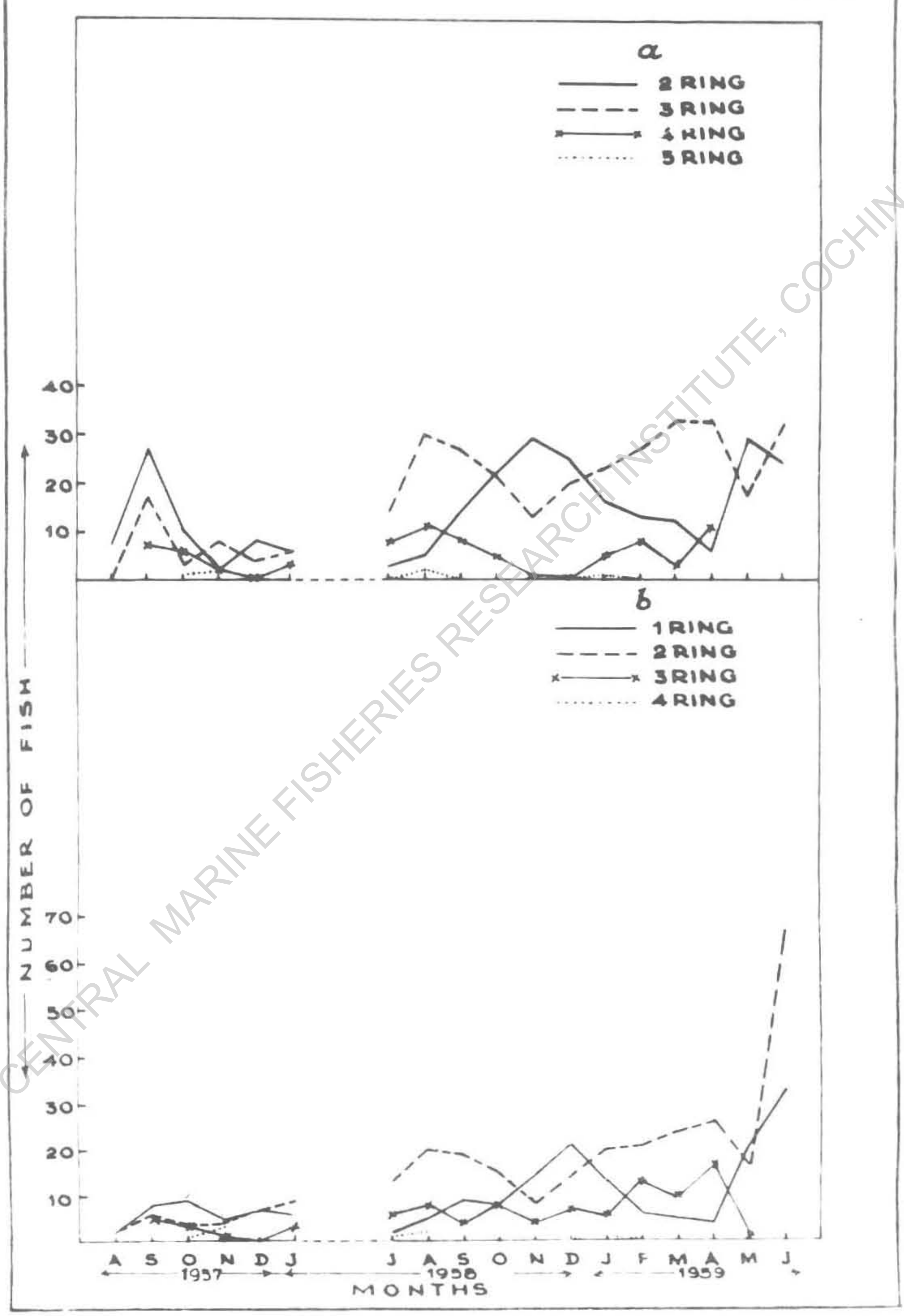
Table 7 for scales is prepared on the same lines as for otoliths in Table 6 . The number of rings on scales varies from 1 - 4 (Fig. 10). The first ring on the scale is seen mostly when the fish attains a length of 83 mm, and likewise the second, the third and fourth rings are seen at lengths of 128 mm 158 mm and 188 mm respectively.

From the above it is clear that the appearance of the rings on otoliths bears a close correspondence to those on scales. The larval-ring of otoliths is absent in the scales. The second ring on the otoliths corresponding to the first ring on the scales, the third on the otoliths to the second on the scales, the fourth on the otoliths to the third on the scales and finally the fifth on the otoliths to the fourth on the scales are seen at the fish lengths of 83mm, 128 mm, 158 mm and 188 mm respectively. The sequence in which the rings appear on the otoliths and scales suggests that they are valid as growth checks in the age determination of the species.

<u>Periodicity in the occurrence of Rings on Otoliths and Scales:</u>

Fig. 11a shows the monthly percentage distribution of the number of rings on the otoliths. Since the larval-ring is present in all the fish above the length of 27 mm, the data in respect of the same are not included in the figure. The peaks for the second ring are seen in the months of September and December 1957, November 1958 and May 1959. The peak occurrence of the third ring was noticed during September and November 1957, August 1958 and March-April 1959. For the fourth ring the peaks

11. Monthly percentage distribution of number of rings on (a) otoliths and (b) scales of *P. heptadactylus*.


a
2 RING
3 RING
4 RING
5 RING
b
1 RING
2 RING
3 RING
4 RING
NUMBER OF FISH
40
30
20
10
70
60
50
40
30
20
10
A S O N D J
J A S O N D J F M A M J
1957
1958
1959
MONTHS

were in the months of August 1958 and February of 1959. Nothing much can be said about the fifth ring for want of adequate data.

Fig. 11b shows the monthly percentage distribution of a number of rings on the scales. The peak occurrence for the first ring are seen during the months of October and December 1957 and September and December 1958; for the second ring during August 1958 and April 1959 and for the third ring during August, October and December 1958, February and April 1959. As in the case of otoliths nothing can be said about the fourth ring on scales because of the paucity of material.

Validity of Rings on Otoliths and Scales in Age Determination

Formation of rings of annual nature on the hard parts like otoliths and scales in fishes, is attributed primarily to the retardation or cessation of growth brought about either by too low temperatures in winter or by metabolic strain after the act of spawning. Winter growth checks were found by Arora (1951) on the scales of California sand dab and by Hagerman (loc.cit.) on the otoliths and scales of Dover sole. Fairbridge (loc.cit.) has found on the otoliths of tiger flathead the annulus forming in winter but has observed no direct relation between its formation and the sea water temperature. Blackburn (loc.cit.) considered the annual growth checks on the otoliths and scales of Australian pilchard to be spawning checks. Seshappa and Bhimachar (loc.cit.) have termed the growth rings as"monsoon rings" in the scales of *Cynoglossus semifasciatus*. They observe that retardation of growth does not extend to the entire monsoon period and that food is not the only factor responsible for the formation of growth checks. They state that some adverse environmental factors connected with the south-west monsoon, possibly . lead to the formation of the growth rings which are annual in character.

It is noticed that the rings on the otoliths and scales of *P. heptadactylus* are seen in majority of fish during the periods September-November and March-May. The feeding intensity in this species does not show marked seasonal variation during any part of the year and thus it is unlikely that food may be the possible cause in the formation of these growth checks. Since these rings are formed during and even before monsoon, it is not possible to state with certainty how far the monsoon conditions may advertisely affect the rate of growth in this species.

It has already been stated that the second, third, fourth and fifth otolith rings and correspondingly the first second, third and fourth scale rings appear at an average length of 83 mm, 128 mm, 158 mm and 188 mm respectively. Apparently these rings are annual in nature. The causes of the formation of the growth checks in *P. heptadactylus* are not known. In some fishes like the Australian pilchard spawning checks have been recorded but is not likely that those found in *P. heptadactylus* have any relation to spawning periodicity as they are found even in those fish which are one year old and sexually immature. According to Rounsefell and Everhart (1953) growth in a fish is said to be indeterminate as the fish continues to grow even in extreme old age. In the earlier part, the growth rate is fast, in extreme old age the limiting growth is reached with exceeding slowness. As contrasted with this, the growth in most mammals has a maximum speed in early part of life and then slowing down reaches a point beyond which there is practically no growth. This latter type is known as determinate growth. Fitting in with the general pattern of growth of a fish, it may be seen that P.heptadactylus has a fairly rapid rate of growth in the first year, viz. 83 mm; growth rate thereafter decreases slowly and gradually, being 45 mm in the second year, 30 mm each in the third and fourth years. It may also be stated here as detailed in the account to follow that the growth rate in the higher age-groups is still much less, being 24 mm each in fifth and sixth years and 18 mm each in seventh and eighth years.

Rate of Growth in Males and Females

Differences in the growth rate between males and females are generally met with in fishes as pointed out by Fairbridge (loc.cit.) in tiger flathead, by Orcutt (loc.cit.) in starry flounder and by Hagerman (loc.cit.) in Dover sole. In all these three fishes the rate of growth was found to be higher after a certain age in the females which grew to a larger size than the males. An attempt is made here to find out if there exists any difference in the growth rate between the two sexes of P. heptadactylus by regrouping the percentage distribution of rings on otoliths and scales separately for males and females at 15 mm class interval.

It is seen from the Tables 8 and 9 that the mid-points of the size-groups for females range from 83 mm to 248 mm while those for males from 98 mm to 188 mm. In females the second ring on the otoliths and the first on the scales appear at a length of 83 mm. In males the corresponding otolith ring makes its appearance in fish of 98 mm but not the scale ring. However, the first and second rings on scales in the males are noticed at 128 mm. This is because number of specimens at these lengths was small in the samples. Again in females, the fifth ring on the otoliths and fourth on the scales appear at 188 mm whereas these are not seen in the males at this length, because the number of males found at this length is very small. At this length when 109 females showed rings on otoliths and 90 on scales, only 4 males showed rings on otoliths and 2 on scales. It is the rarity of males that offers lesser opportunity in tracing the maximum number of rings on otoliths and scales at this length. But for these two minor discrepancies that may hardly have any effect on the growth rates, the appearance of rings at different lengths in both the sexes is identical. It is evident from this that the growth rates in males and females of this species, are equal in the same age-groups. Rarity of males at the size-group with the midpoint 188 mm and the total

Table 8.

Percentage frequencies of number of rings on the otoliths of male and female *P. heptadactylus* at each of 15 mm length-groups.

Size-group (Mid-point mm)	Male (Number of rings)				Female (Number of rings)			
	2	3	4	5	2	3	4	5
83	-	-	-	-	100	-	-	-
98	100	-	-	-	100	-	-	-
113	100	-	-	-	100	-	-	-
128	90	10	-	-	79	21	-	-
143	79	21	-	-	64	36	-	-
158	54	39	7	-	34	60	6	-
173	41	53	6	-	21	70	9	-
188	25	75	-	-	5	77	17	1
203	-	-	-	-	2	56	40	2
218	-	-	-	-	-	50	45	5
233	-	-	-	-	8	42	42	8
248	-	-	-	-	-	11	67	22

Table 9

Percentage frequencies of number of rings on the Scales of male and female *P. heptadactylus* at each of 15 mm length-groups.

Size-group (Mid-point mm.)	Males (Number of rings)				Females (Number of rings)			
	1	2	3	4	1	2	3	4
83	-	-	-	-	100	-	-	-
98	-	-	-	-	100	-	-	-
113	-	-	-	-	100	-	-	-
128	93	7	-	-	82	18	-	-
143	78	22	-	-	65	35	-	-
158	68	26	6	-	30	67	3	-
173	21	64	15	-	12	84	4	-
188	-	100	-	-	4	49	46	1
203	-	-	-	-	8	30	56	6
218	-	-	-	-	-	65	30	5
233	-	-	-	-	10	40	40	10
248	-	-	-	-	-	50	25	25

absence beyond this and also the availability of the largest male of 210 mm as against 273 mm of a female in the catch, indicates that survival of males after completing 4 years is remote. Comparatively the females grow to a much larger size and live longer than the males.

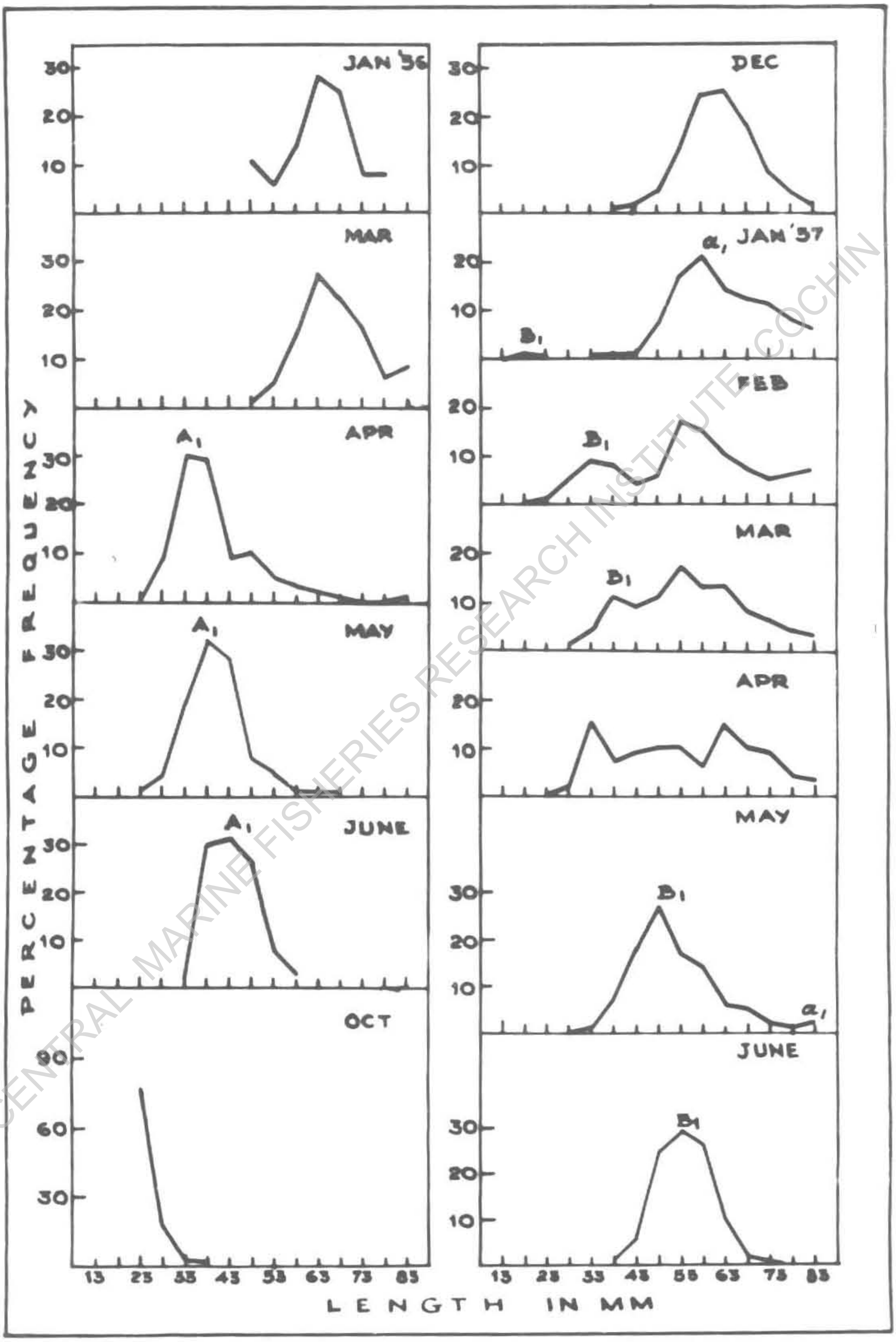
Length Frequency Distribution

Length frequency distributions in commercial catches are commonly used in estimating the age and rate of growth of a fish by tracing the progression of dominant size-groups at specified time intervals.

Samples for this study were collected from 'Dol' and trawl nets. Consistent differences were noticeable in the size composition of *P. heptadactylus* landed by these two gears. The mesh size at the cod end of the 'Dol' net being as small as /0.75 mm, *P. heptadactylus* of the size of even 15 mm were collected when this gear was operated. The cod end of the trawls had their meshes ranging from 50.8 mm to 63.5 mm. Hence, smaller specimens from the trawls were always absent. It was therefore felt necessary to analyse the data separately for these two types of gears. 'Dol' nets were operated in the inshore waters of Bombay, otter trawls just outside the Bombay harbour and bull-trawls from Bombay to Dwarka in the north. However, it was not possible to analyse the data area-wise for trawlers, because the catches from different areas were always mixed up before landing.

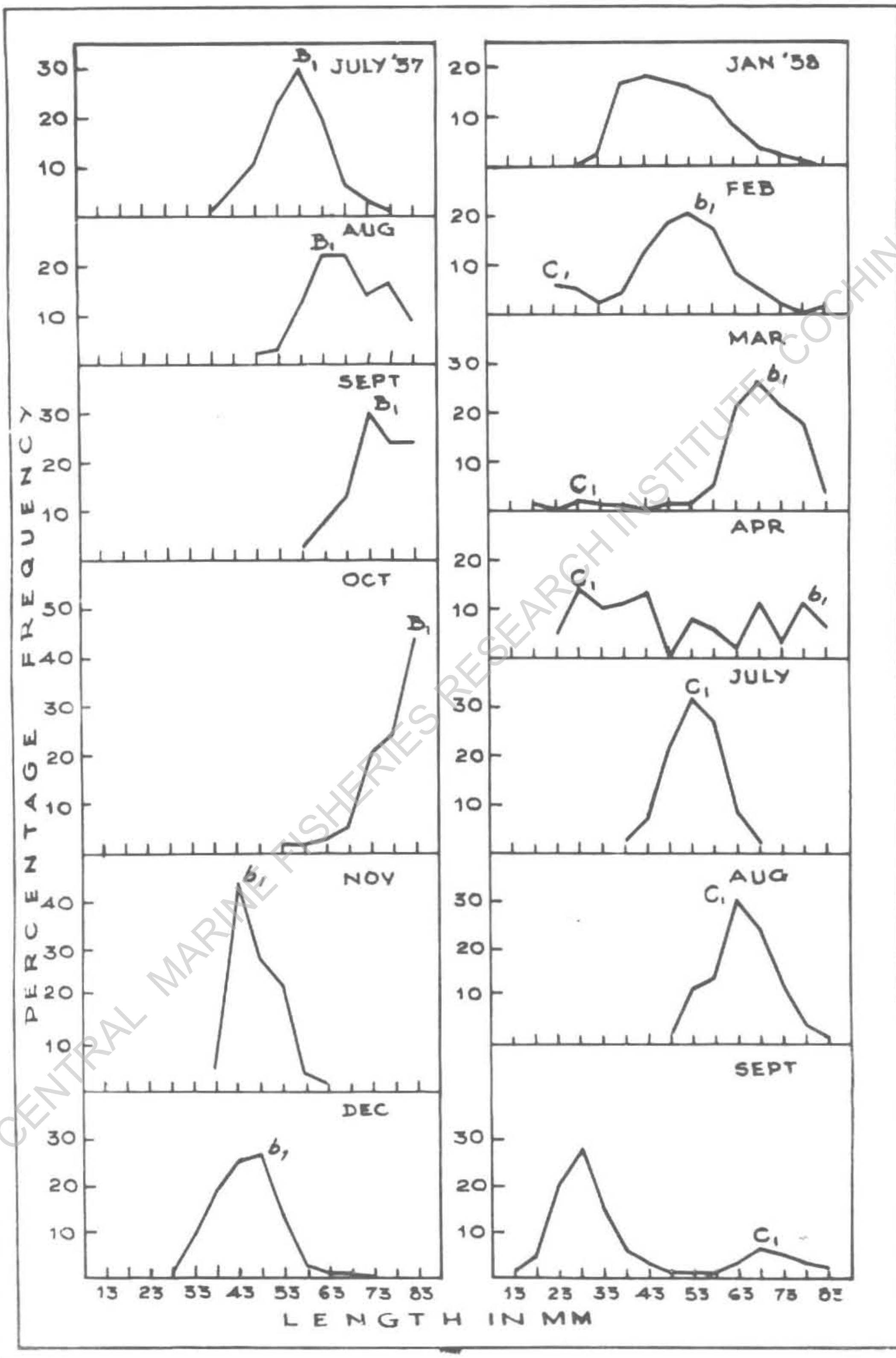
The size range in the 'Dol' catch was from 15 mm to 225 mm whereas that in the trawl catch, was from 32 mm to 273 mm. This size range of 15 mm to 273 mm was divided first into 15 mm class intervals. The frequency polygons were drawn for both the gears. It was found that there was no shifting of the modes from month to month to indicate the growth rate. From the studies on otoliths and scales it has been found that the monthly growth rates in all the year-groups are less than 15 mm. This is the probable reason why the shift of modes was not seen. Hence, with the help of otolith and scale studies, the fish were divided into year-groups. The size range in each year-group was divided into 5 mm class intervals. The growth rate goes on decreasing with the age and so with these class intervals, the increase in length in the higher age-groups was not noticeable. But to have uniformity in the analysis, the same 5 mm class interval was maintained throughout. Accordingly in the first year-group there are 15 size-groups, in the second 9 and in the third and fourth 6 each. Above the fourth year it is not possible to make out the rate of growth because the addition of rings on both the otoliths and scales is not discernible. So fish above four years were all grouped together irrespective of their age into 17 size-groups. The modes in the frequency polygons are named by capital letters and small letters for convenience, the capital letters indicating postmonsoon recruitment and small letters the premonsoon recruitment. The numbers accompanying these letters

12 a. Rate of growth in the first year-group of *P. heptadactylus* in 'Dol' samples.



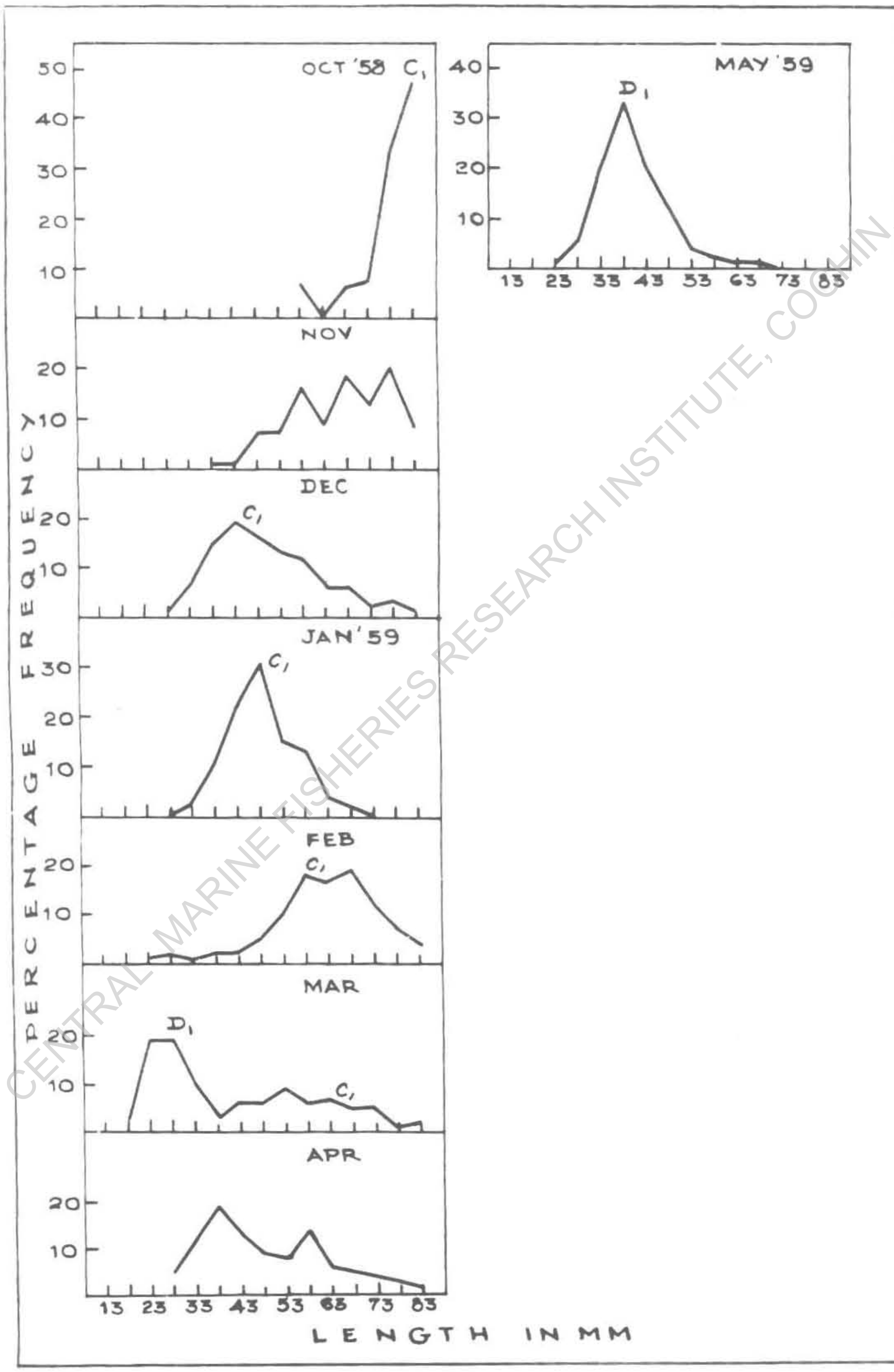
PERCENTAGE FREQUENCY
JAN '56
MAR
APR
A1
MAY
A1
JUNE
A1
OCT
DEC
a1 JAN '57
B1
FEB
B1
MAR
B1
APR
MAY
B1
a1
JUNE
B1
13 23 33 43 53 63 73 83
LENGTH IN MM

12 b. Rate of growth in the first year-group of P. heptadactylus in 'Dol' samples.



JULY '57
AUG
SEPT
OCT
NOV
DEC
JAN '58
FEB
MAR
APR
JULY
AUG
SEPT
B1
b1
C1
PERCENTAGE FREQUENCY
LENGTH IN MM
13 23 33 43 53 63 73 83

12 c. Rate of growth in the first year-group of *P. heptadactylus* in 'Dol' samples.



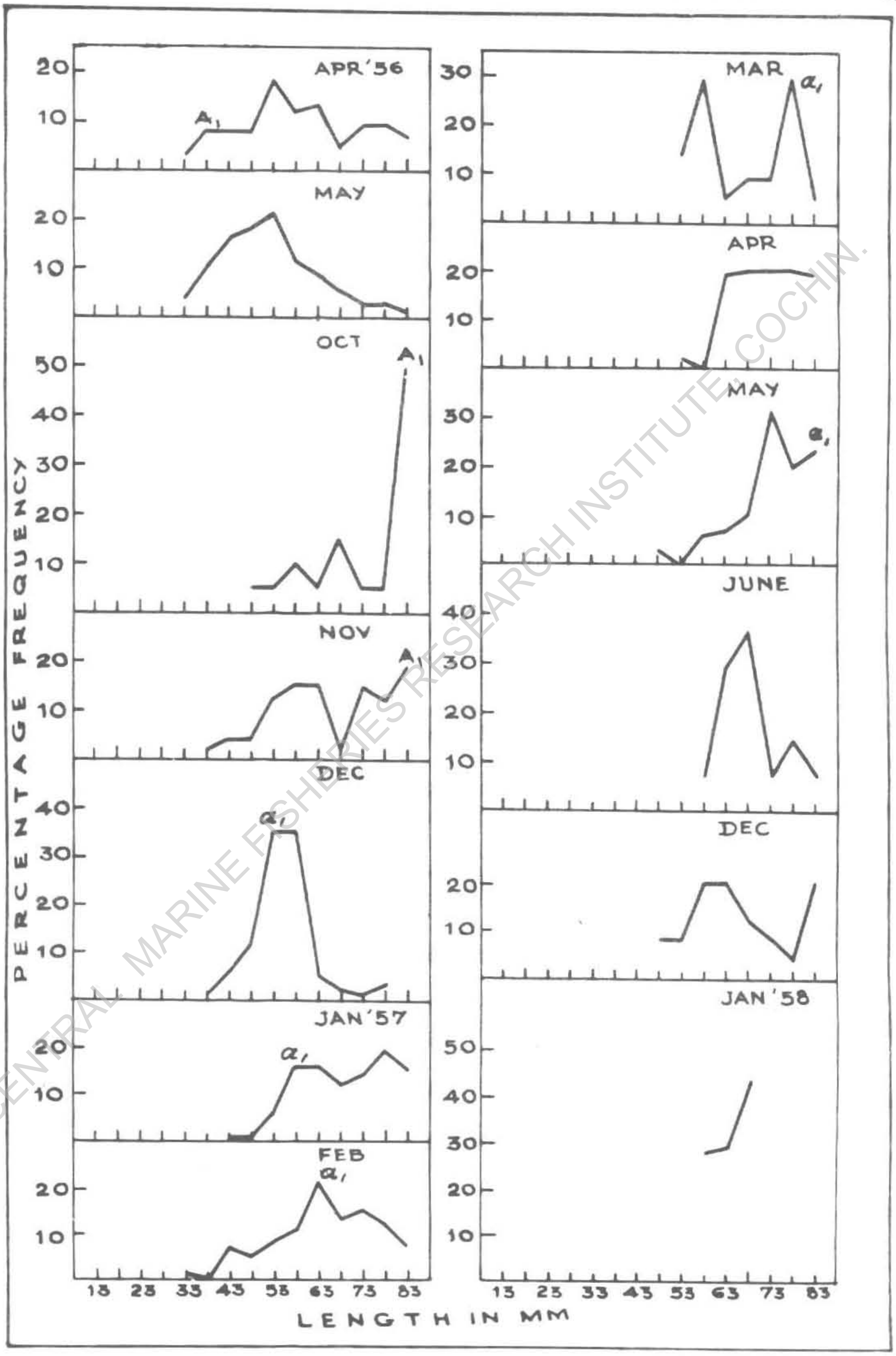
OCT '58
C₁
NOV
DEC
JAN '59
FEB
MAR
D₁
APR
MAY '59
PERCENTAGE FREQUENCY
LENGTH IN MM
13 23 33 43 53 63 73 83

indicate the year-groups to which the fish belong. The higher age-groups have also been treated separately with 3 mm class intervals and their average monthly rates of growth were determined.

First-year-group:- During the first year of life the fish grows to an average size of 83 mm as seen from the studies on the otoliths and scales.

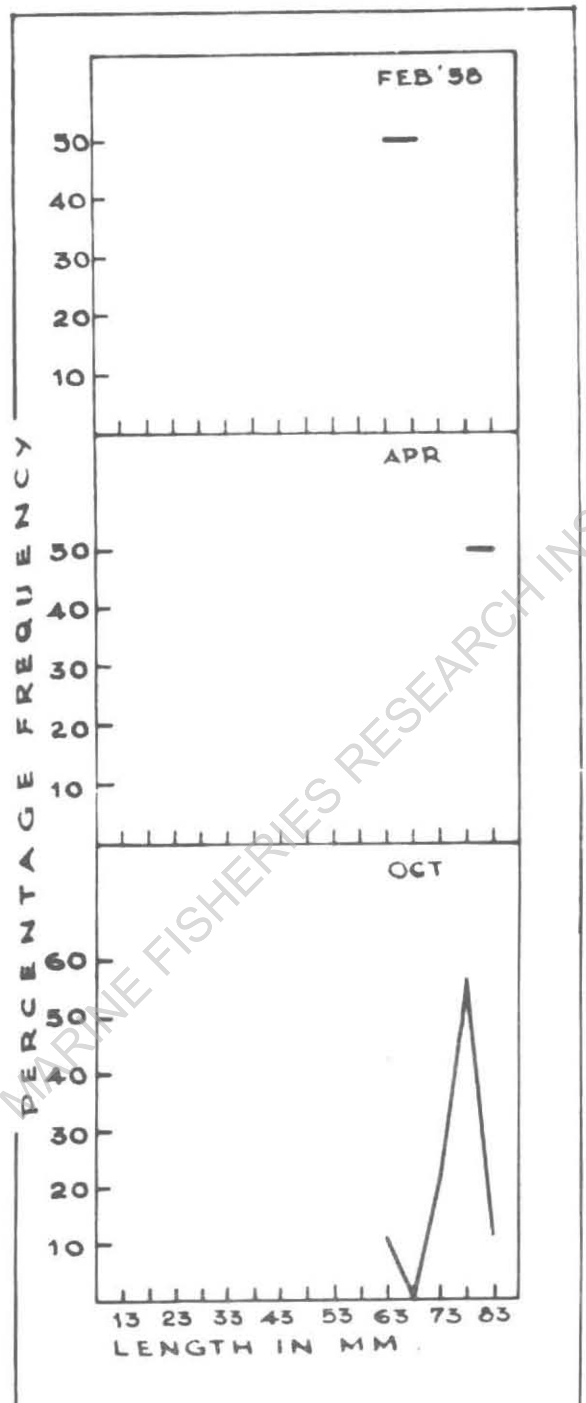
Fig. 12a - 12 c show the frequency polygons for 'Dol' net samples for the years 1956-1959. It is seen from the Fig.12a that there is a mode 'A_1' at 33 mm in the month of April 1956. This can further be traced to 43 mm to which length it reaches in the month of June with an average monthly growth of 5 mm. Two modes 'B_1' and 'a_1' are seen at lengths 18 mm and 58 mm respectively in the month of January for 1957 samples. The mode 'B_1' can be traced right upto the month of October (Fig. 12b) when it shifts to 83 mm with an average monthly increment of 7.2 mm. The mode 'a_1' is seen again only in the month of May (Fig. 12a) at length 83 mm with a growth of 25 mm in four months. In November 1957 (Fig. 12b) another mode 'b_1' is seen at 43 mm and it moves on to 48 mm in the subsequent month of December. The difference between the modal values of 'B_1' and 'a_1' in January 1957 is 40 mm. The mode 'B_1' takes about 6 months to show an increase of 40 mm as it appears at this length in the month of July. Hence, the mode 'a_1' appears to be 6 months older than the mode 'B_1'. Similarly the mode 'b_1' represents a group 6 months younger than 'B_1'. In February 1958 (Fig.12b) two modes, 'C_1' at 23 mm and

13 a. Rate of growth in the first year-group of *P. heptadactylus* in trawl samples.



APR '56
MAY
OCT
NOV
DEC
JAN '57
FEB
MAR
APR
MAY
JUNE
DEC
JAN '58
PERCENTAGE FREQUENCY
LENGTH IN MM
13 23 33 43 53 63 73 83

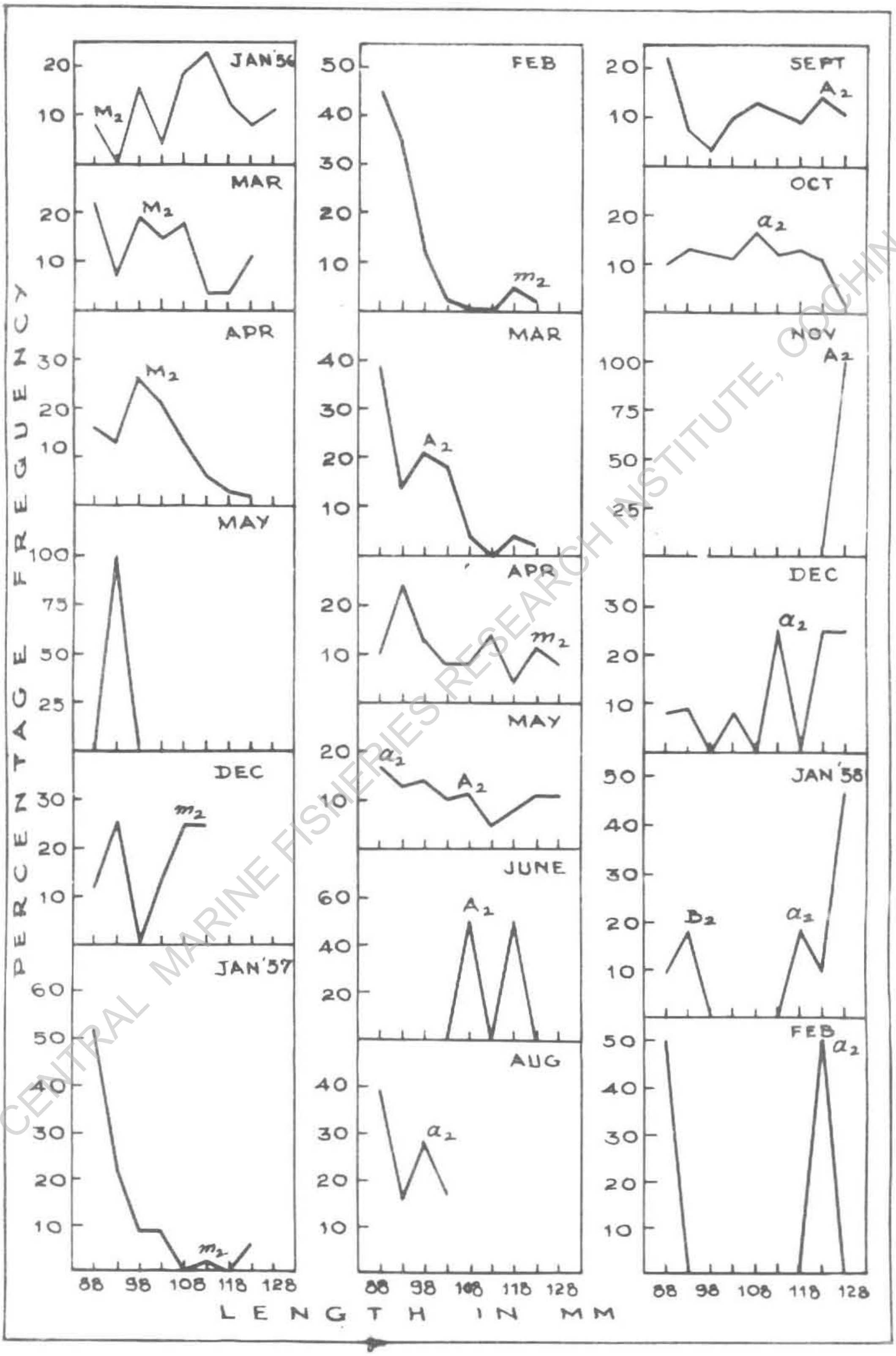
13 b. Rate of growth in the first year-group of *P.heptadactylus* in trawl samples.


FEB '58
50
40
30
20
10
APR
50
40
30
20
10
OCT
60
50
40
30
20
10
PERCENTAGE FREQUENCY
13 23 33 43 53 63 73 83
LENGTH IN MM

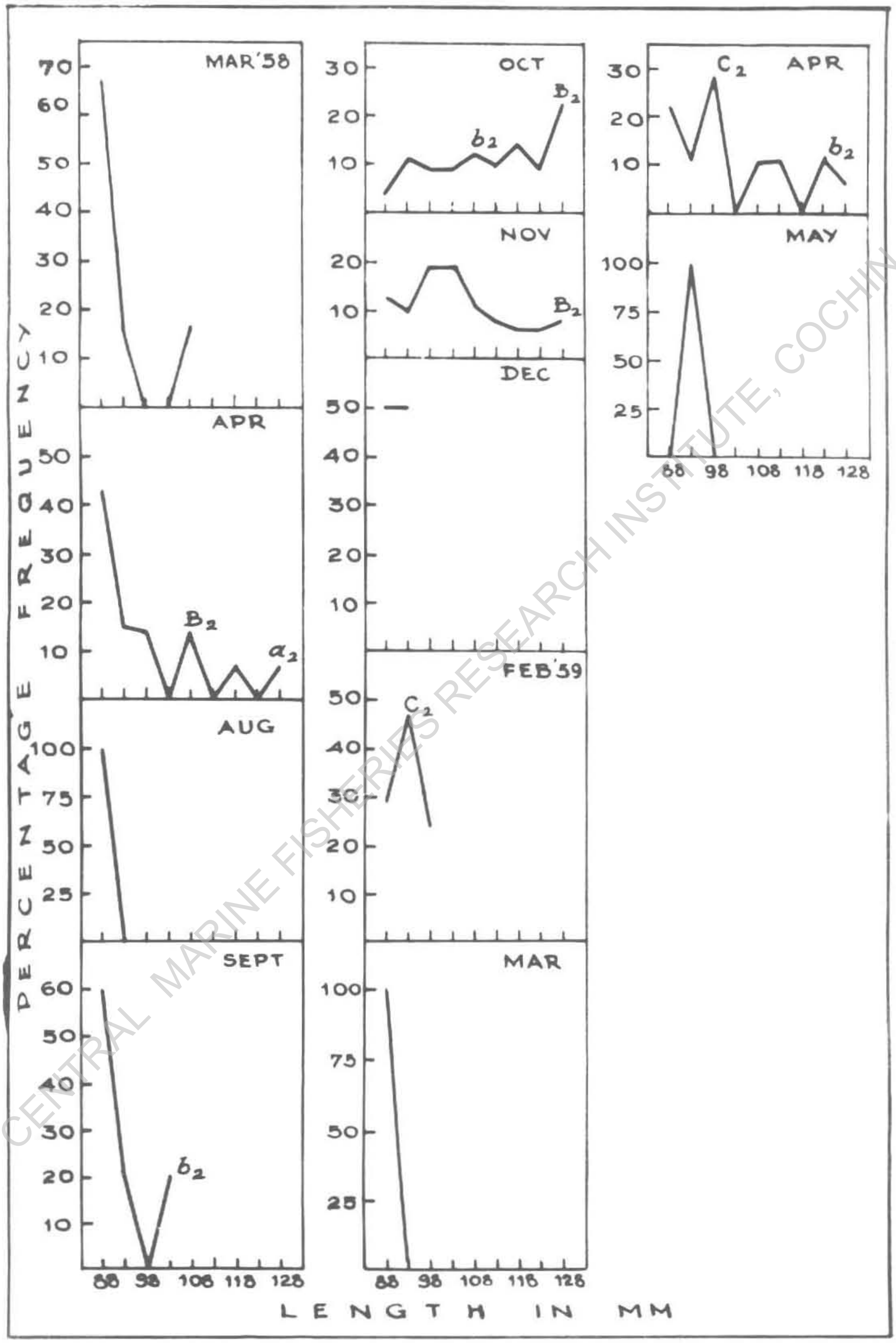
and 'b_1' at 53 mm are seen. The mode 'C_1' progresses steadily till it reaches 83 mm in the month of October (Fig. 12c). The mode 'b_1' moves on to 78 mm in the month of April 1958 (Fig.12b). It can be seen that the mode 'b_1' is the continuation of the one seen in November 1957 at 43 mm. This has thus grown 35 mm in 7 months with an average monthly increase of 5 mm. The average monthly growth rate for the mode 'C_1' is 7.5 mm. The mode 'c_1' at 43 mm is seen during December 1958 (Fig. 12c) and this can be further traced through January to March 1959 when it has a value of 63 mm. This shows an increase of 20 mm in 3 months with the monthly growth rate of 6.3 mm. In the month of March 1959 another mode 'D_1' is seen at 28 mm which shifts on to 38 mm in May.

It is obvious from the Figs.13a & b that the first year-group is not well represented in the trawl samples. In the year 1956 two modes, namely, 'A_1' in April and 'a_1' in December (Fig. 13a) are seen at 38 mm and at 53 mm respectively. There are two modes in October and November at the same length of 83 mm. These can be considered as the continuation of 'A_1' mode of April without appearing in the months in between. The mode 'a_1' of December 1956 can further be traced in the year 1957 to 83 mm in the month of May. It can be seen that the growth in these five months is 30 mm with an average monthly increase of 6 mm. Almost the same growth-rate can be observed in the case of mode 'A_1' at 38 mm which shifts on to 83 mm in October and remains in the same length in November. This first year-group is almost absent except a few

14 a. Rate of growth in the second year-group of
P. *heptadactylus* in 'Doi' samples.


JAN'56
MAR
APR
MAY
DEC
JAN'57
FEB
MAR
APR
MAY
JUNE
AUG
SEPT
OCT
NOV
DEC
JAN'58
FEB
PERCENTAGE FREQUENCY
LENGTH IN MM
88 98 108 118 128

14 b. Rate of growth in the second year-group of
<u>P.heptadactylus</u> in 'Dol' samples.



MAR'58
APR
AUG
SEPT
OCT
NOV
DEC
FEB'59
MAR
APR
MAY
PERCENTAGE FREQUENCY
LENGTH IN MM
88 98 108 118 128

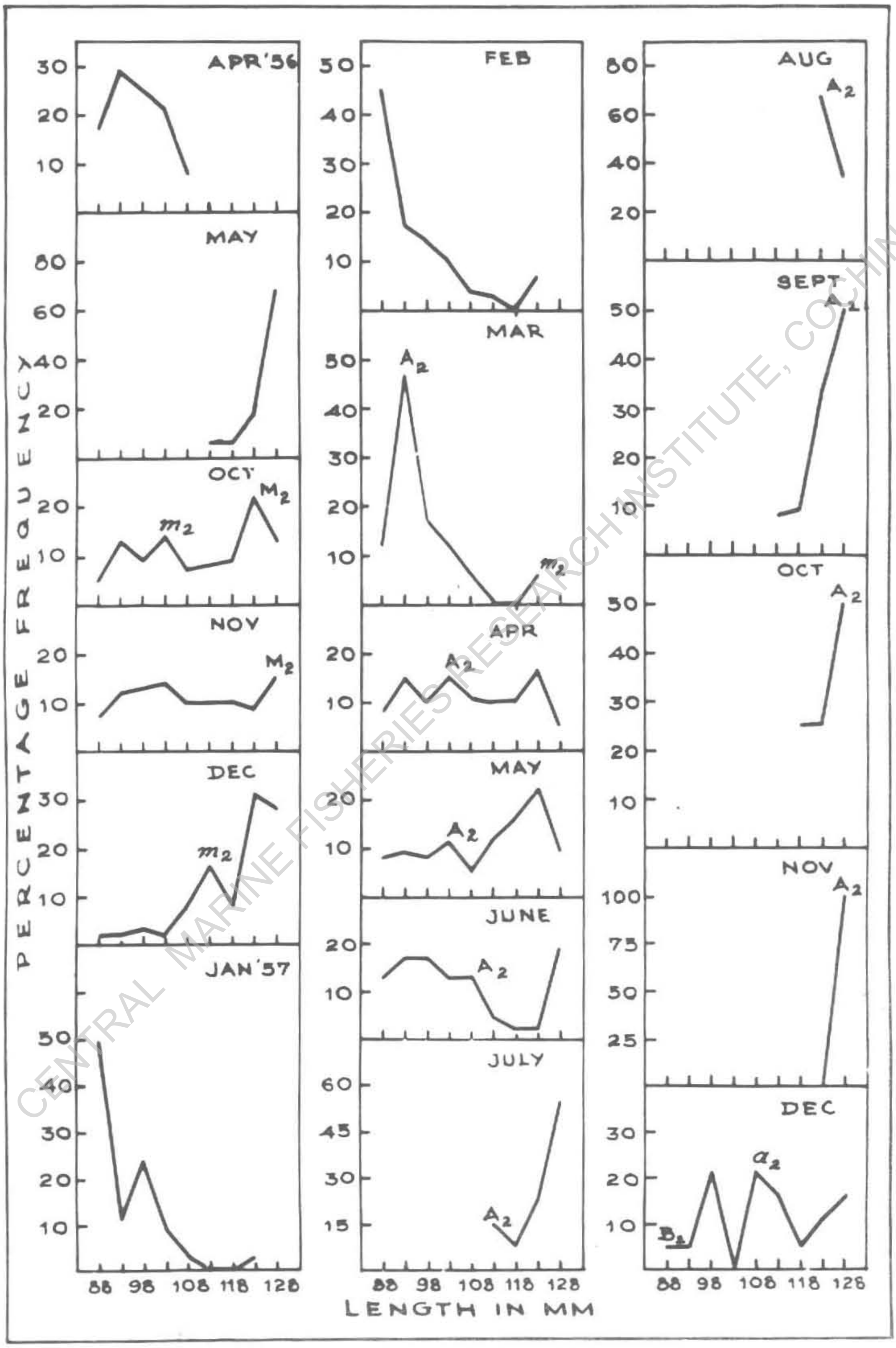
stray individuals in the samples collected during the years 1958 and the first half of 1959.

Second year-group: From the studies on otoliths and scales the growth of this fish during the second year of its life is 45 mm and fish attains an average size of 128 mm by the end of second year.

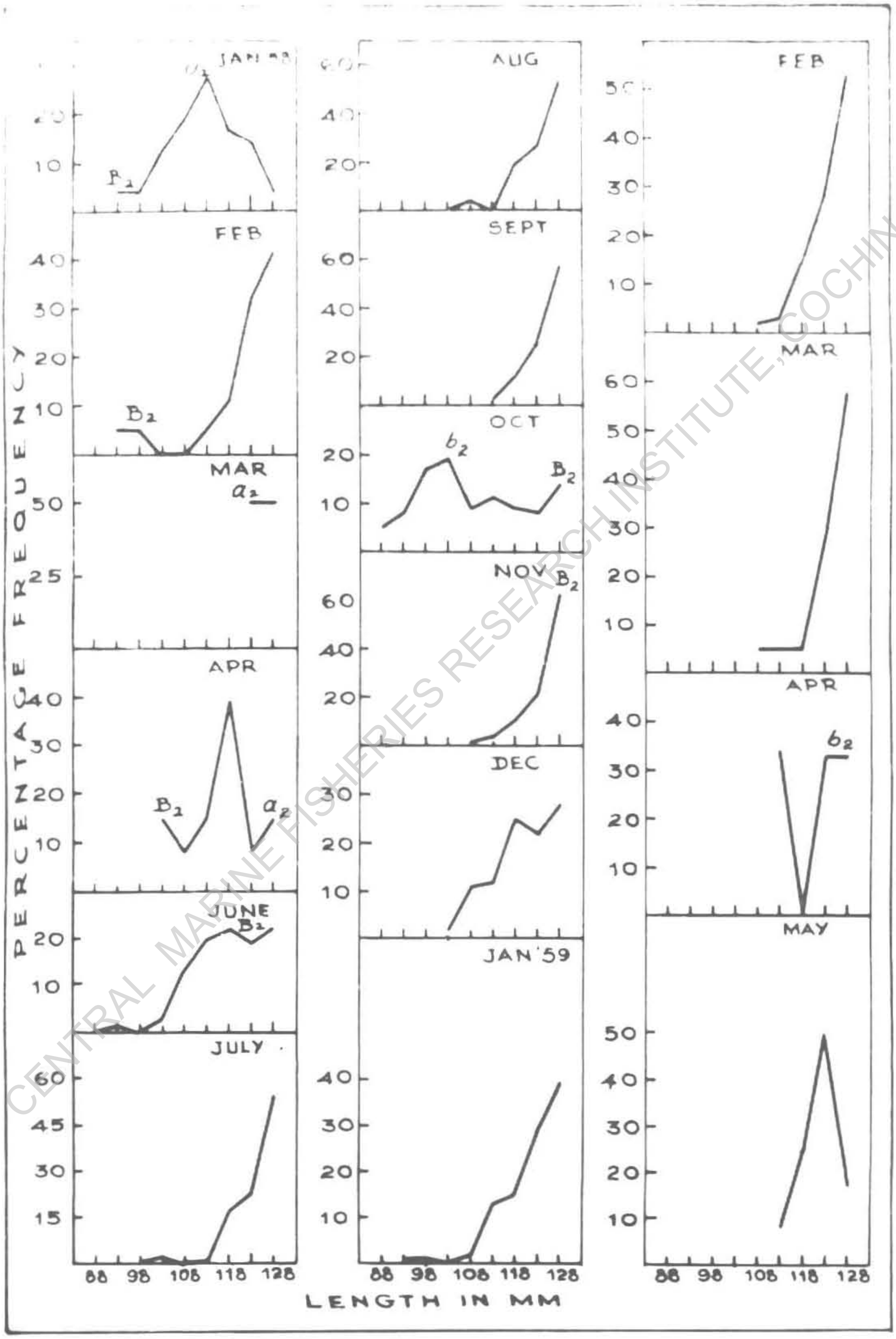
In Fig. 14a the 1956 sample for 'Dol' net shows one mode 'M_2' at 88 mm in the month of January which moves on to 98 mm in April with an average increment of 3.3 mm per month and another 'm_2' at 108 mm in December which is traceable upto April 1957 when it reaches the size of 123 mm with an average monthly increase of 3.75 mm. Two other modes, namely, 'A_2' at 98 mm in March and 'a_2' at 88 mm in May 1957 can be traced to 128 mm in the months of November 1957 and April 1958 respectively (Figs. 14a & b). The average monthly growth rates in these cases work out to be 3.75 mm and 3.63 mm respectively. In 1958, two other modes 'B_2' and 'b_2' at 93 mm and 103 mm respectively are seen (Figs. 14a & b). Of these 'B_2' of January can be traced to November when it moves on to 128 mm. The 'b_2' of September is seen at 108 mm in October and at 123 mm in April 1959. The monthly growth rates for 'B_2' and 'b_2' are 3.5 mm and 3.0 mm respectively. The mode 'C_2' of February 1959 at 93 mm moves on to 103 mm in April 1959 (Fig.14b).

It can be seen from the Figs. 15a & b that the second year-group is well represented in all the trawl samples. The mode

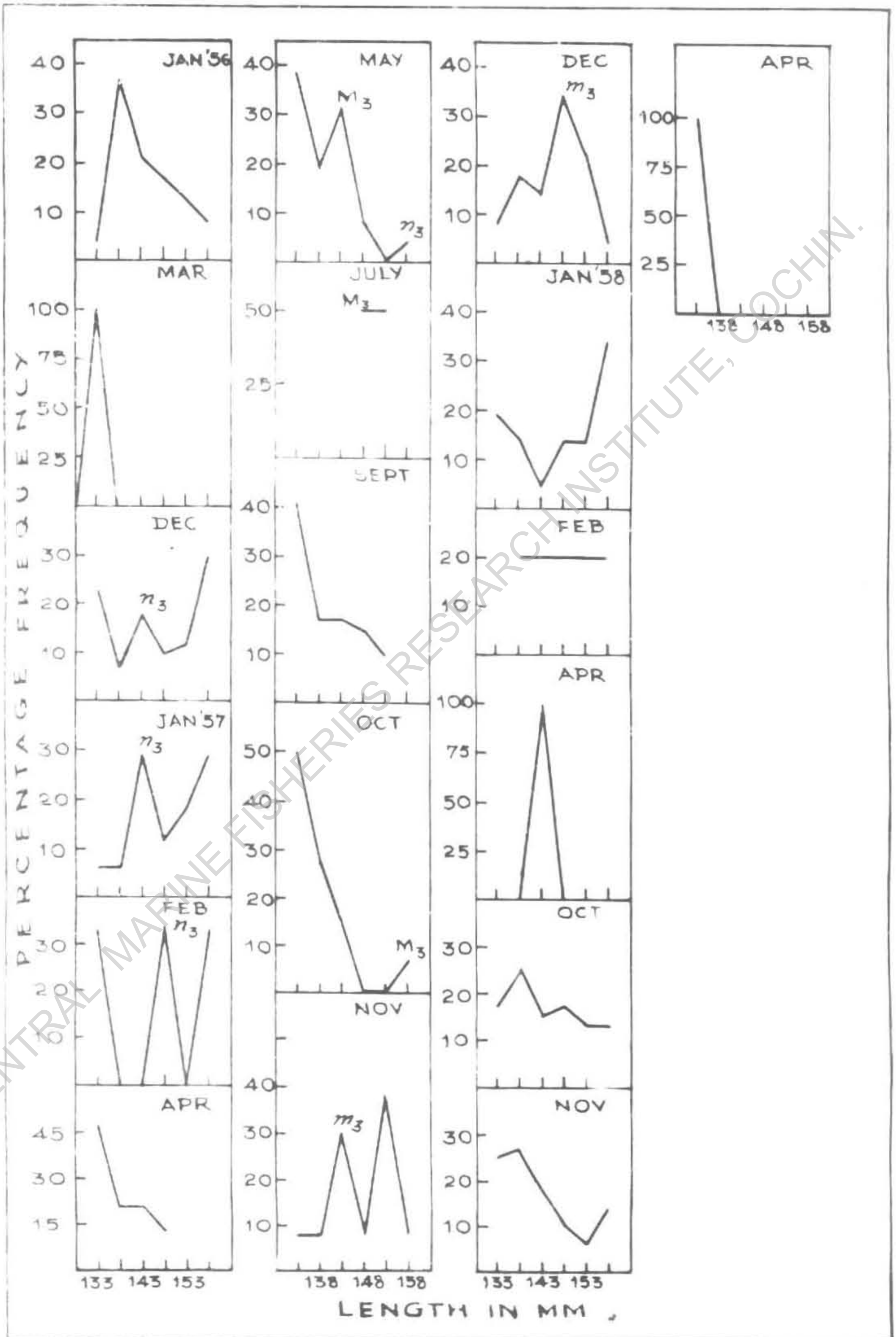
15 a. Rate of growth in the second year-group of *P.heptadactylus* in trawl samples.


APR '56
MAY
OCT
NOV
DEC
JAN '57
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
m_2
M_2
A_2
a_2
B_2
PERCENTAGE FREQUENCY
LENGTH IN MM
88 98 108 118 128

15.b. Rate of growth in the second year-group of *P.heptadactylus* in trawl samples.


JAN '58
AUG
FEB
SEPT
MAR
OCT
APR
NOV
JUNE
DEC
JULY
JAN '59
MAY
PERCENTAGE FREQUENCY
LENGTH IN MM
88 98 108 118 128

18. Rate of growth in the third-year group of
<u>P. heptadactylus</u> in 'Dol' samples.



JAN '56
MAR
DEC
JAN '57
FEB
APR
MAY
JULY
SEPT
OCT
NOV
DEC
JAN '58
FEB
APR
OCT
NOV
APR
PERCENTAGE FREQUENCY
LENGTH IN MM.

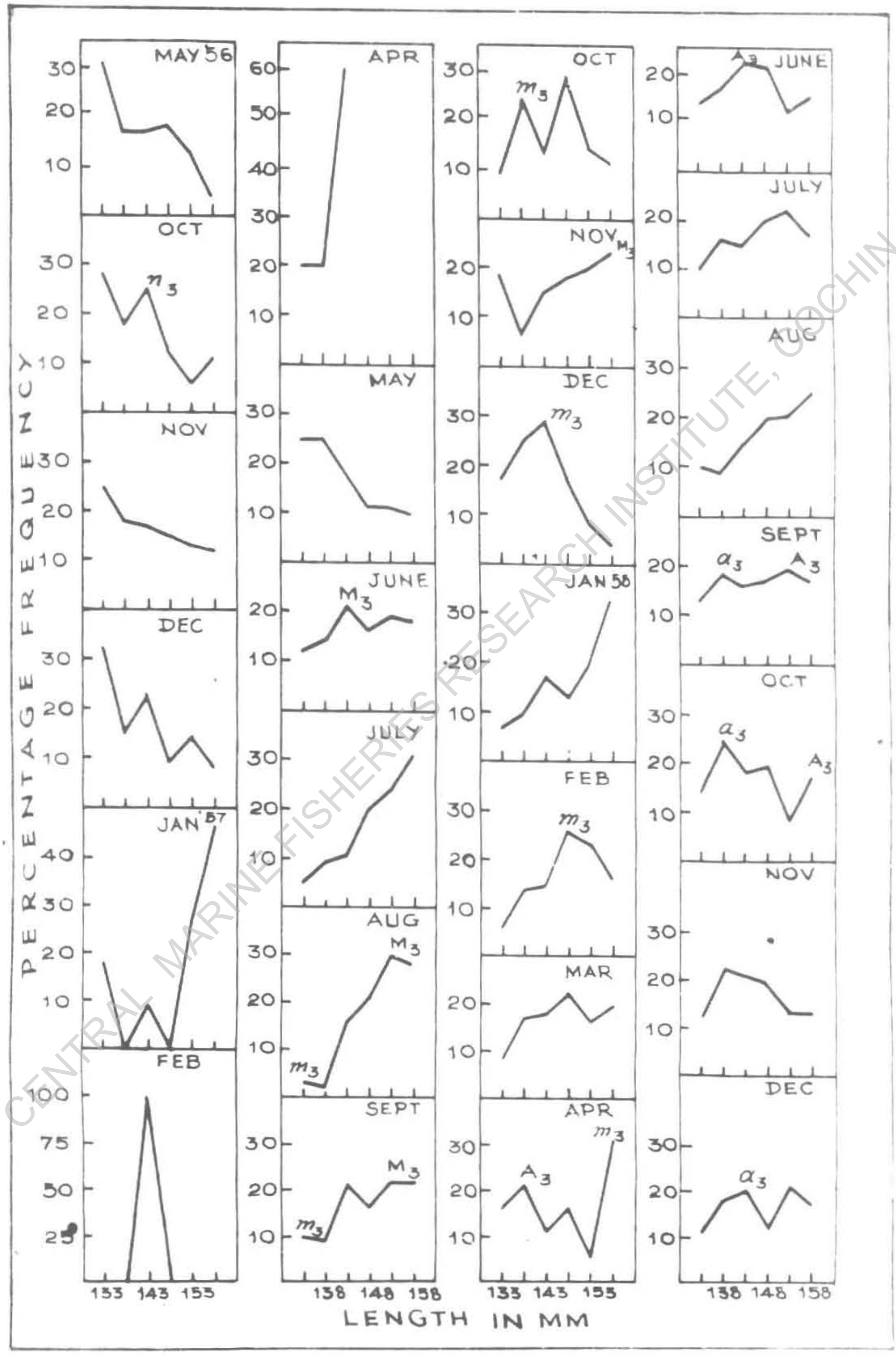
'm_2' of October 1956 at 103 mm is traceable right upto 123 mm in the month of March 1957 (Fig. 15a) with an average monthly increment of 4 mm. The modes 'A_2' and 'a_2' at 93 mm and 108 mm respectively are seen in the months of March and December 1957. 'A_2' can be traced further to the length of 128 mm during November with an average monthly increase of 4.35 mm and 'a_2' in April 1958 (Fig.15b) giving an average increment of 5 mm per month. The mode 'B_2' at 88 mm appearing in December 1957 (Fig. 15a) can be traced further upto 128 mm in the month of November 1958 (Fig. 15b) with an average of 3.63 mm per month. In the year 1958, mode 'b_2' at 103 mm seen in the month of October can be traced in April 1959 to 123 mm with an average monthly increment of 3.3 mm.

Third year-group:- Growth during the third year is estimated to be 30 mm and the fish attains the size of 158 mm by the end of third year.

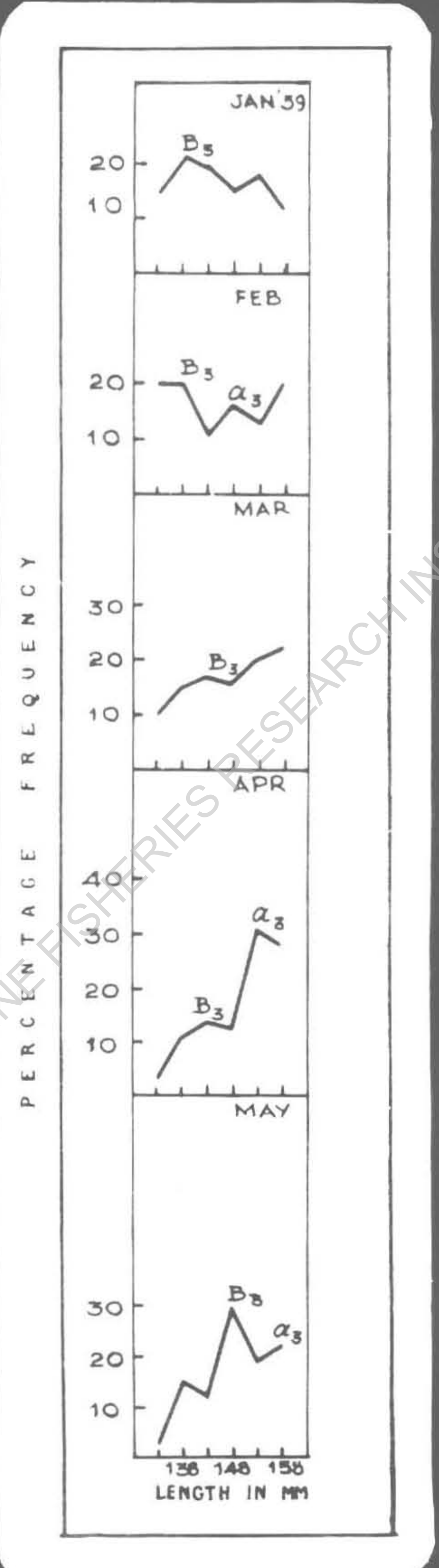
In the 'Dol' net samples (Fig. 16), mode 'n_3' at 143 mm appearing in December 1956 progresses further to 158 mm in May 1957 with an average monthly increase of 3 mm. In the year 1957 two modes 'M_3' and 'm_3' are seen at 143 mm in the months of May and November respectively, 'M_3' can be traced further to the length 158 mm in October, giving an average increase of 3 mm per month. 'm_3' is seen at the very next size-group of 148 mm in the month of December.

In the trawl samples (Fig.17a) only one mode 'n_3' at

17 a. Rate of growth in the third-year-group of *P. heptadactylus* in trawl samples.


PERCENTAGE FREQUENCY
LENGTH IN MM
MAY 56
OCT
NOV
DEC
JAN 57
FEB
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN 58
FEB
MAR
APR
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
133
143
153
138
148
158
133
143
153
138
148
158

17 b. Rate of growth in the third year-group of *P. heptadactylus* in trawl samples.


JAN '59
FEB
MAR
APR
MAY
PERCENTAGE FREQUENCY
LENGTH IN MM
138
148
158

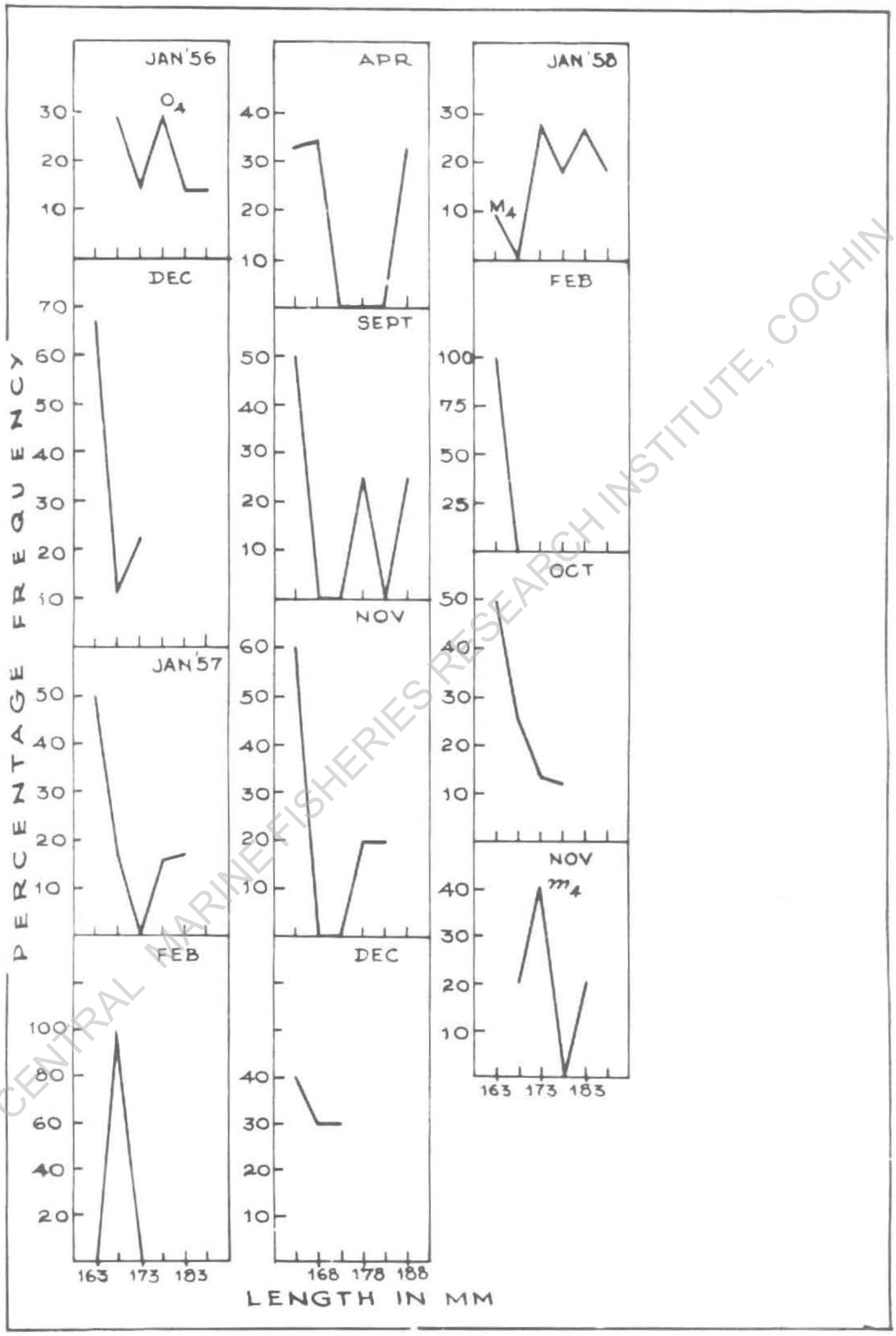
143 mm is seen in October 1956. Its growth could not be traced further because this group was not represented in the subsequent months. In the year 1957 two modes 'M_3' at 143 mm and 'm_3' at 133 mm are seen in the months of June and August respectively. 'M_3' moves further to the size of 158 mm during the month of November while 'm_3' to the same length during April 1958. The monthly rate of increment for both the groups is 3 mm. Other modes represented in the year 1958 are 'A_3' at 138 mm in the month of April and 'a_3' at 138 mm in the month of September. 'A_3' shifts on to 158 mm in October 1958 with an average monthly increase of 3.3 mm and 'a_3' to 158 mm in May 1959 (Fig. 17b) with an average monthly increment of 2.5 mm. 'B_3' appearing in January 1959 at 138 mm moves on to 148 mm in the month of May with an average monthly increase of 2.5 mm.

<u>Fourth year-group</u>:- In fourth year the growth of 30 mm is the same as that in the third year and the fish attains the length of 188 mm at the end of fourth year.

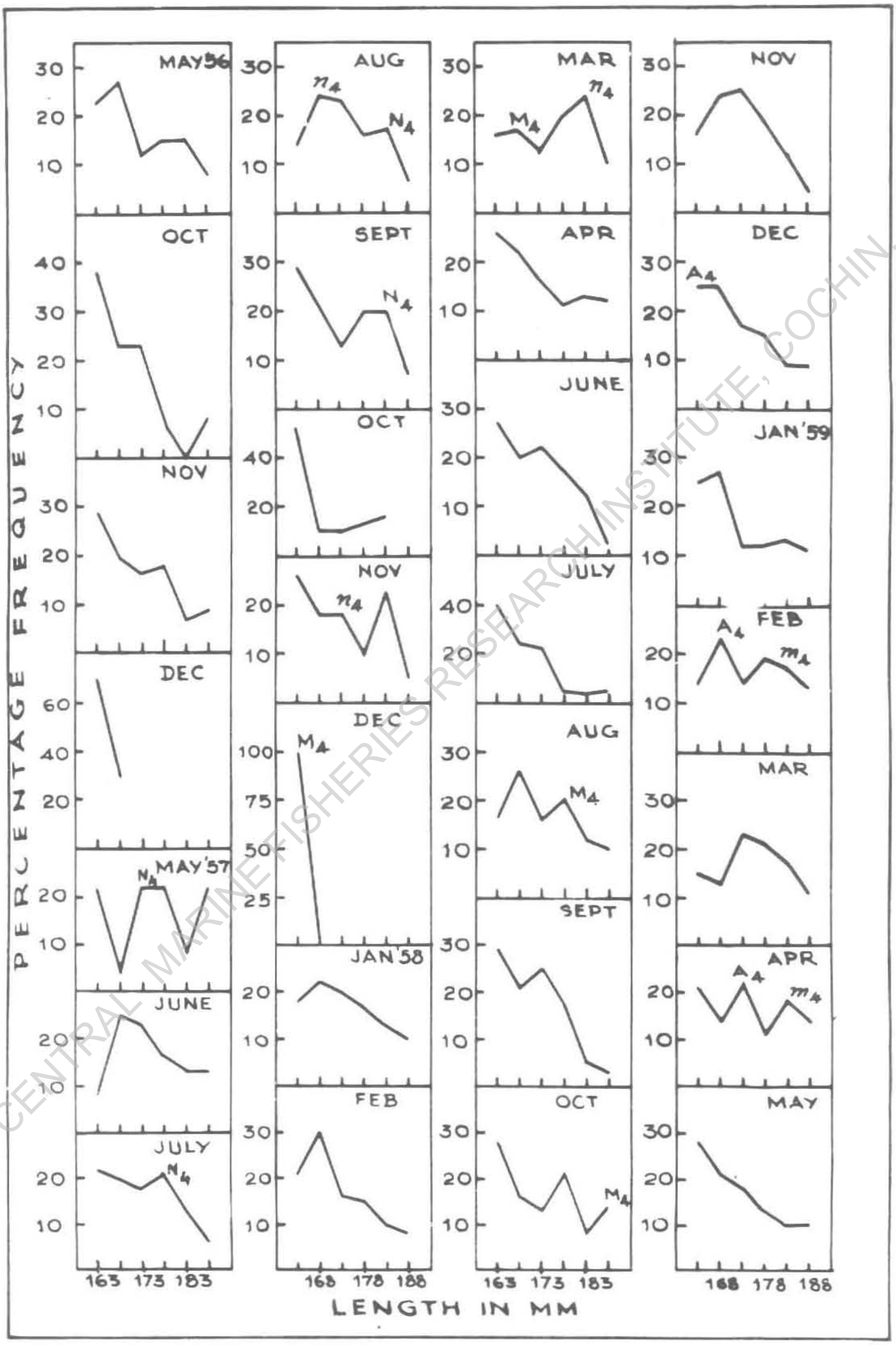
In 'Dol' net samples (Fig. 18) this year-group is poorly represented. One mode 'o_4' in the year 1956 is seen in the month of January at 178 mm. In the year 1958 two modes 'M_4' and 'm_4' are seen at 163 mm and 173 mm respectively, the former in the month of January and the latter in November. This year-group is not represented in the years 1957 and 1959.

In the trawl samples (Fig. 19) of 1956 the fourth year-group is not represented. There modes 'N_4' and 'n_4' and 'M_4' are seen in

18. Rate of growth in the fourth year-group of *P.heptadactylus* in 'Doi' samples.


PERCENTAGE FREQUENCY
LENGTH IN MM
JAN'56
O_4
DEC
JAN'57
FEB
APR
SEPT
NOV
DEC
JAN'58
M_4
FEB
OCT
NOV
m_4
163 173 183
168 178 188

19. Rate of growth in the fourth year-group of *P. pentadactylus* in trawl samples.


PERCENTAGE FREQUENCY
LENGTH IN MM
MAY'56
OCT
NOV
DEC
MAY'57
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN'58
FEB
MAR
APR
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN'59
FEB
MAR
APR
MAY
163 173 183
168 178 188
163 173 183
168 178 188

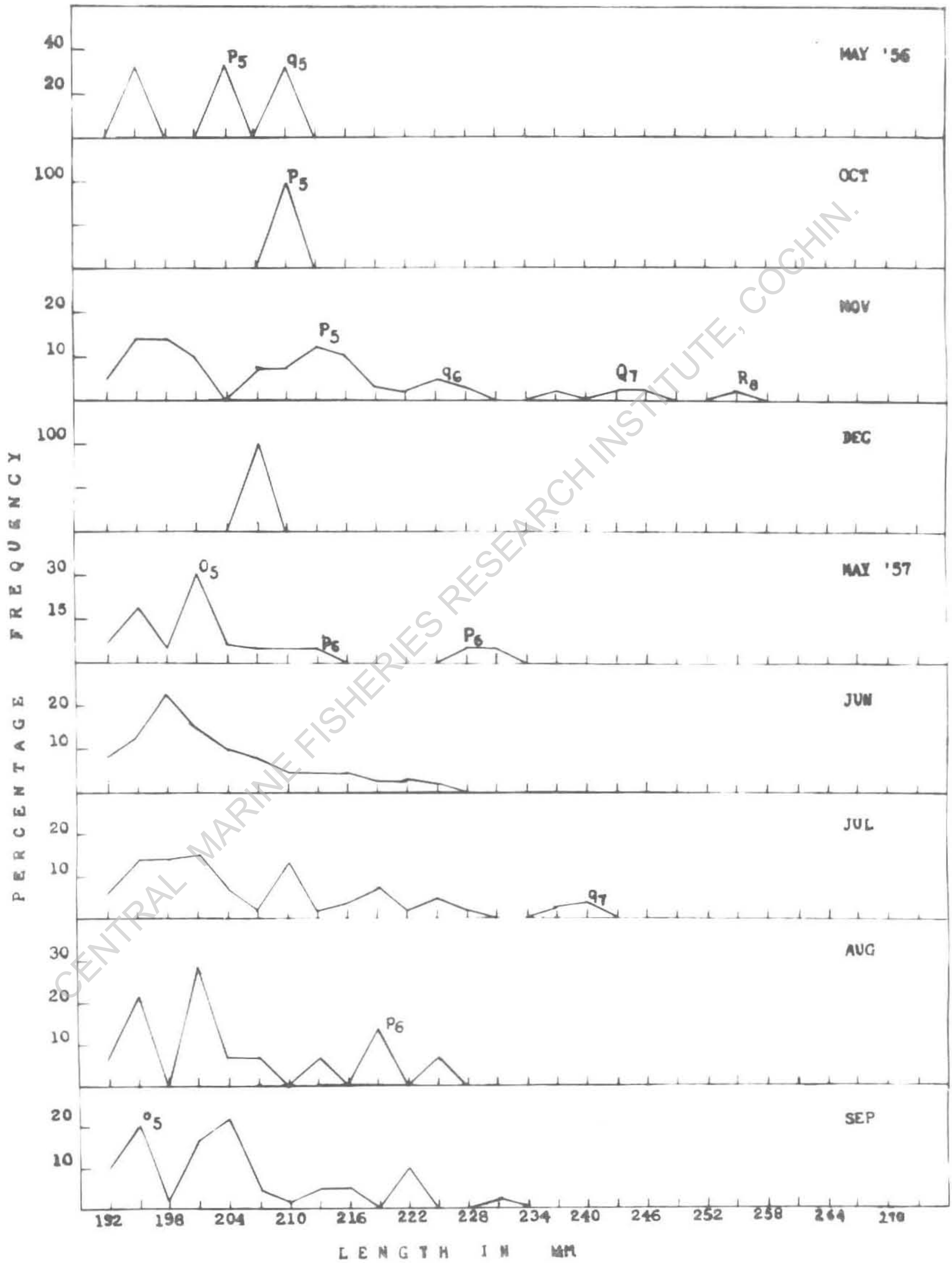
the year 1957. 'N_4' at 173 mm appearing in May moves on to 183 mm in September, giving an average of 2.5 mm per month. 'n_4' at 168 mm seen in August shifts to 183 mm in March 1958 with an average increment of 2.1 mm per month. 'M_4' at 163 mm in December increases 25 mm by the end of October 1958 with an average monthly increment of 2.5 mm. ~~on an average~~. The mode 'A_4' of December 1958 appearing at 163 mm can be traced to the length of 173 mm in April 1959 with an average monthly increase of 2.5 mm. 'm_4' at 178 mm seen in February 1959 appears again at 183 mm in the month of April. The growth in this case is also 2.5 mm per month.

<u>Higher age-groups:</u> -

It is seen that the studies on otoliths and scales are not helpful in calculating the growth and growth rates beyond the fourth year-group. The attempt to follow the progression of frequency polygons for this fish beyond ~~the~~ 188 mm in their fifth and above age-groups with 5 mm class interval in conformity with the earlier age-groups, did not yield any encouraging results. The possibility of smaller monthly increment in the growth with the advance in age, being the cause for this failure, fish beyond the length of 188 mm were grouped further into smaller ranges of 3 mm class interval.

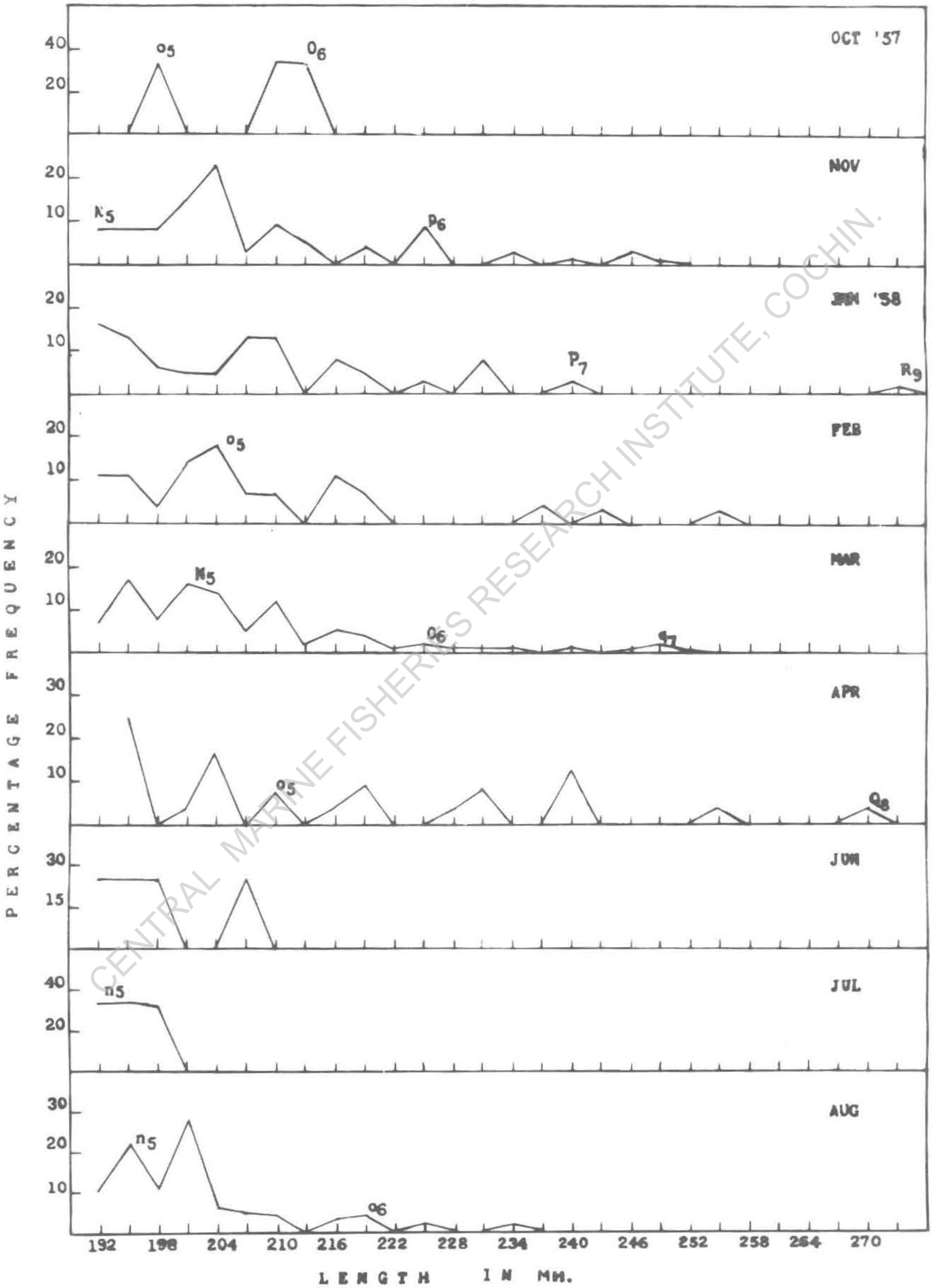
In the 'Dol' net samples only 3 fish of the lengths 191 mm, 195 mm and 225 mm were recorded during this study. The number being too small nothing could be done to trace the growth for higher age-groups occurring very rarely in the 'Dol' net. However, the trawlers landed 882 *P. heptadactylus* above the length of 188 mm.

20 a. Rate of growth in higher age-groups of
P. heptadactylus in trawl samples.

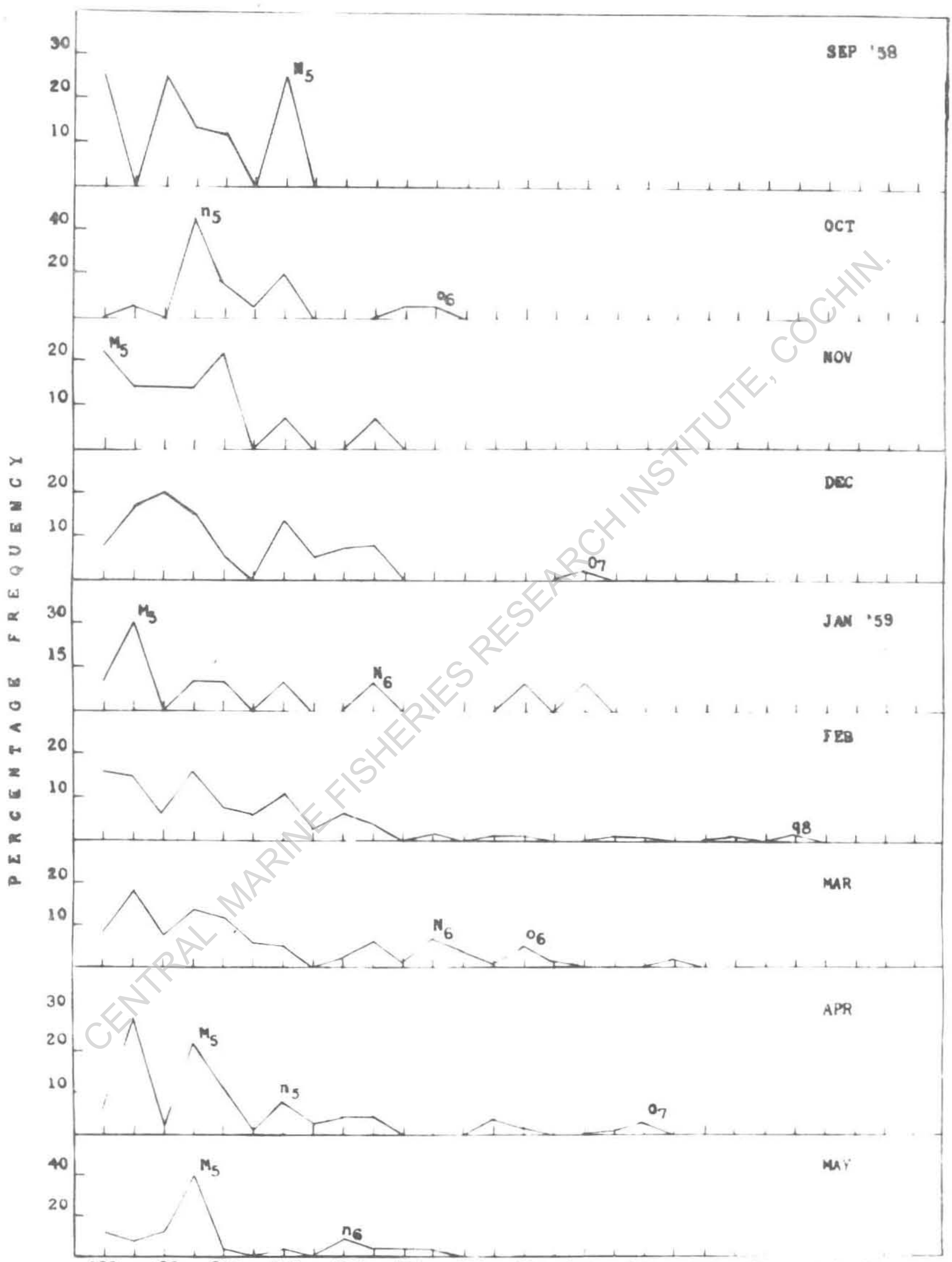


MAY '56
OCT
NOV
DEC
MAY '57
JUN
JUL
AUG
SEP
PERCENTAGE FREQUENCY
LENGTH IN MM
192
198
204
210
216
222
228
234
240
246
252
258
264
270

20 b. Rate of growth in higher age-groups of *P. heptadactylus* in trawl samples.


OCT '57
NOV
JAN '58
FEB
MAR
APR
JUN
JUL
AUG
PERCENTAGE FREQUENCY
LENGTH IN MM.
192
198
204
210
216
222
228
234
240
246
252
258
264
270

20 c. Rate of growth in higher age-groups of *P. heptadactylus* in trawl samples.



SEP '58
OCT
NOV
DEC
JAN '59
FEB
MAR
APR
MAY
PERCENTAGE FREQUENCY
LENGTH IN MM.
192
198
204
210
216
222
228
234
240
246

These were grouped, with 3 mm class intervals and size frequency polygons were drawn as shown in Figs. 20a - 20c.

It is seen from the Fig. 20a that the mode 'o_5' at 195 mm appearing in September 1957 moves to 210 mm in 7 months recording an increase of 15 mm by April 1958 (Fig. 20 b) and it re-appears after 11 months in March 1959 (Fig. 20c) with an increase of 24 mm. Another mode 'P_5' at 204 mm in May 1956 (Fig. 20a) shows an increase of 24 mm in 12 months and appears again at 228 mm in May 1957. It can be traced further at 240 mm in January 1958 (Fig. 20b) showing an increase of 12 mm during the course of 8 months. The mode 'q_5' of May 1956 (Fig. 20a) at 210 mm shifts by 30 mm more in 13 months and is seen at 240 mm in July 1957. The same mode can be traced to 249 mm in March 1958 (Fig. 20b) with an additional growth of 9 mm in 8 months and still further to 261 mm in February 1959 (Fig. 20c) showing an increment of 12 mm in 11 months. The mode 'R_8' at 255 mm appearing in November 1956 (Fig. 20a) reappears after 14 months at 273 mm in January 1958 (Fig. 20b); like-wise, other modes shown in the figure can also be traced further in different years.

From this it can be seen that P.heptadactylus grows to the age of 9 years, the growth in each of the fifth and sixth years being about 24 mm and in the seventh and eighth years being about 18 mm. It can be stated that this fish when it completes the fifth, sixth, seventh and eighth years, will measure about 213 mm, 237 mm, 255 mm and 273 mm respectively.

To maintain uniformity in the description with the first four year classes, the higher age-groups are also described in similar manner as seen in the following account.

Fifth year-group:- In the year 1956, two modes 'P_5' and 'q_5' (Fig. 20a) appear in the samples of May at the lengths 204 mm and 210 mm respectively. 'P_5' progresses further to 213 mm in November with an average monthly increase of 1.5 mm. The mode 'q_5' cannot be traced further. Three modes 'O_5', 'o_5' and 'N_5' appear in 1957. 'O_5' which is at 201 mm in May is not traceable in the following months. 'o_5' at 195 mm in September, moves further to 210 mm in April 1958 (Fig.20b) with an average monthly increment of 2.14 mm. 'N_5' at 192 mm in November shows an increase of 18 mm by September 1958 (Fig. 20c) with an average growth of 1.8 mm per month. Modes 'n_5' and 'M_5' are seen in July (Fig.20b) and November (Fig.20c) of 1958 respectively at 192 mm. 'n_5' can be traced further in April 1959 to 210 mm, the increase in length being on an average 2 mm. 'M_5' is 201 mm by April-May with an average growth of 1.8 mm per month.

Sixth year-group:- The sixth year group is represented by the mode 'q_6' in 1956 at 225 mm in the month of November (Fig.20a) and is not traceable further. In 1957 the mode 'P_6' is seen at 228 mm in May. Another mode 'p_6' at 213 mm in May is seen to move further upto 225 mm in November (Fig.20b) showing an average monthly increment of 2 mm. One more mode 'O_6' at 213 mm appearing in October can be traced in March 1958 to 225 mm with an average monthly growth of 2.4 mm. The mode 'o_6' in August 1958 at 219 mm moves on to 234 mm in March 1959 (Fig.20c), the average growth shown being 2.1 mm per month.

'N_6' in January 1959 at 219 mm shows an increase of 6 mm by March. Mode '$n_6$8 is seen at 216 mm in May 1959 but is not traceable further for want of data.

Seventh year-group:- This year-group is represented by the mode 'Q_7' at 243 mm in November 1956 (Fig. 20 a) and 'q_7' in July 1957, 'P_7' in January 1958 (Fig. 20b) and 'O_7' in December 1958 (Fig. 20 c) at 240 mm. Of these, 'O_7' can be traced further to 246 mm in April showing an average increase of 1.5 mm per month.

Eighth year-group:- Three modes 'R_8' at 255 mm in November 1956, (Fig. 20 a), 'Q_8' at 270 mm in April 1958 (Fig. 20 b) and 'q_8' at 261 mm in February 1959 (Fig. 20 c) are seen.

Ninth year-group:- The only mode 'R_9' at 273 mm respresents this year-group in January 1958 (Fig. 20 b).

From the length frequency studies it can be said that P.heptadactylus grows with a monthly average rate of 6 mm to 7 mm in the first year of life, 3.5 mm to 4 mm in the second year, about 3 mm in the third, 2.5 mm in the fourth, 2 mm in the fifth and sixth and lastly about 1.5 mm in each of the seventh and eighth years. The conclusions drawn from the otolith and scale studies almost agree with the results obtained from the length frequency studies for the first four years of its life. The differences of small magnitude amounting to 0.5 mm to 1 mm between these two results may be due to the personal error in taking measurements. No difference in the rate of growth between the samples from the two

Table

Growth of the year classes of *P. heptadactylus* in

				1		9		5		6						1		9		5		7	
Mid-point mm.	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
13													B_1										
18																							
23																							
28																							
33				A_1										B_1									
38					A_1										B_1								
43						A_1																	b_1
48																	B_1						
53																		B_1					
58													a_1						B_1				
63																				B_1			
68																							
73																					B_1		
78																							
83																	a_1					B_1	
88	M_2																a_2						
93																							
98			M_2	M_2											A_2					a_2			
103																							
108												m_2					A_2	A_2				a_2	
113													m_2										
118														m_2									
123																m_2					A_2		
128																							A_2
133																							
138																							
143												n_3	n_3				M_3						m_3
148														n_3					M_3				
153																							
158																	n_3					M_3	
163																							
168																							
173																							
178	o_4																						

10

local landings of Versova and Sassoon Docks

			1		9		5		8					1959		
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
	C_1															
		C_1	C_1											D_1		
																D_1
											c_1					
												c_1				
	b_1					C_1										
													c_1			
							C_1							c_1		
		b_1						C_1								
			b_1													
									C_1							
B_2													C_2			
															C_2	
								b_2								
			B_2						b_2							
a_2																
	a_2														b_2	
			a_2						B_2	B_2						
M_4																
										M_4						

gears 'Dol' and Trawl is observed.

Making use of these growth rates, it is possible to distinguish two batches recruited in a year during premonsoon and postmonsoon periods. For example fish in the first year of its life indicated by the mode 'A_1' in the month of April 1956 (Fig. 12 a) at a length of 33 mm being 5 months old (with a growth rate of about 6 mm per month), belong to the brood resulting from postmonsoon spawning in about November 1955. Similarly fish indicated by 'a_1' appearing in January 1957 at a length of 58 mm being about 8 months old, must have been recruited in the premonsoon month of May 1956.

Table 10 shows the time of recruitment and growth of P.heptadactylus in different years in 'Dol' net samples. The batches 'A_1' of 1956, 'B_1' of 1957, 'C_1' of 1958 and 'D_1' of 1959 appear to have been recruited in the postmonsoon month November of 1955, 1956, 1957, and 1958 respectively. Of these, 'A_1' and 'B_1' can be traced independently till they complete the second year of life while 'C_1' and 'D_1' cannot be followed up in a similar manner for want of data. The mode 'M_2' of 1956 representing the fish which have completed one year and are in the second year seem to have been recruited in the postmonsoon month of November 1954. This can be traced till 1958 when it is in the fourth year of its life. The batches 'n_3' and 'm_2' of 1956, 'a_1' and 'b_1' of 1957 and 'c_1' of 1958 seem to have been recruited in the premonsoon month of May of 1954, 1955, 1956, 1957 and 1958

r

Table

Growth of the year classes of *P. heptadactylus* in the

Mid-point mm.	1956 J	F	M	A	M	J	J	A	S	O	N	D	1957 J	F	M	A	M	J	J	A	S	O	N	D
13																								
18																								
23																								
28																								
33																								
38				A_1																				
43																								
48																								
53												a_1												
58													a_1											
63														a_1										
68																								
73																								
78																								
83										A_1	A_1						a_1							
88																								B
93															A_2									
98																								
103										m_2						A_2	A_2							
108																		A_2						a
113																			A_2					
118												m_2												
123										M_2					m_2					A_2				
128											M_2										A_2	A_2	A_2	
133																				m_3	m_3			
138																						m_3		
143										n_3								M_3						m
148																								
153																				M_3	M_3			
158																							M_3	
163																								M
168																				n_4				
173																	N_4						n_4	
178																			N_4					
183																				N_4	N_4			
188																								
193																							N_5	
198																					o_5			

11

Landings of trawlers

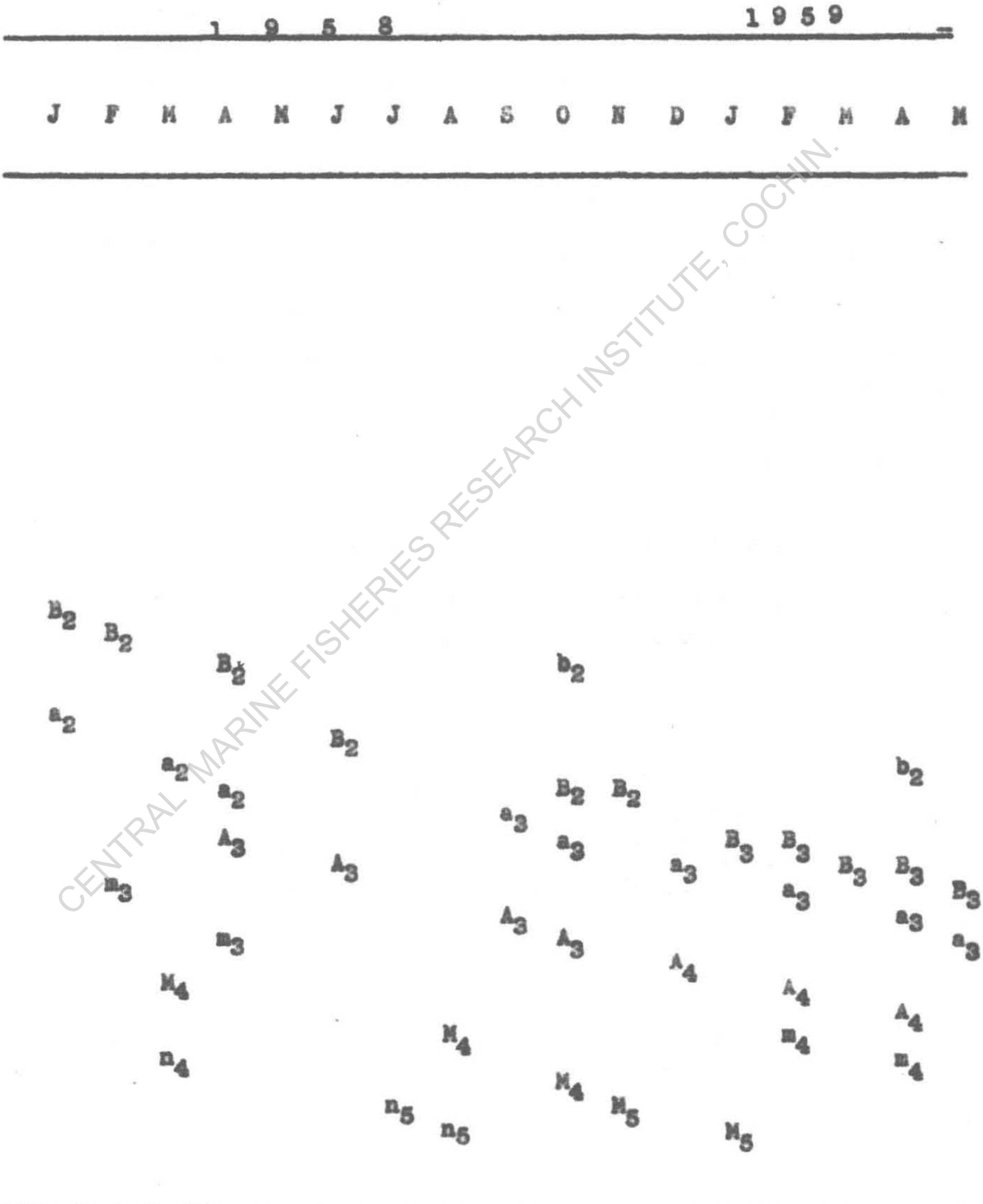


Table 11 (contd.)

Mid-point mm	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
	1956												1957										
198																							
201																	O_5						
204					P_5																		
207																							
210					q_5					P_5													
213											P_5						P_6					O_6	
216																							
219																				P_6			
222																							
223																							
225											q_6												P_6
228																	P_6						
231																							
234																							
237																							
240																			q_7				
243										Q_7													
246																							
249																							
252																							
255											R_8												
258																							
261																							
264																							
267																							
270																							
273																							

1958												1959				
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
		N_5							n_5						M_5	M_5
	o_5															
			o_5					N_5							n_5	
																n_6
							o_6					M_6				
		O_6							o_6					N_6		
														o_6		
P_7											Q_7		O_7		O_7	
		q_7														
													q_8			
			Q_8													
R_9																

respectively. The only mode 'o_4' of the fourth year appearing in 1956 seems to have been recruited in the premonsoon month of May 1952.

Table 11 shows the time of recruitment and growth in different years in trawler samples. Here also two recruitments in a year, namely, the premonsoon and postmonsoon ones are seen. The postmonsoon batches 'R_8', 'Q_7' and 'P_5' of 1956, 'O_5' and 'N_4' of 1957, 'M_3' and 'A_1' of 1956 and 'B_2' of 1957 appear to have been recruited in November of the successive years from 1948 to 1956 with the exception of 1954. The premonsoon batches 'q_5' of 1956 'p_6' and 'o_5' of 1957, 'n_3', 'm_2' and 'a_1' of 1956 and lastly 'b_2' of 1958 seem to have been recruited in May of the successive years from 1950 to 1957 with the exception of May 1955. Almost all these batches can be traced further in the following years till the beginning of 1959. Of these, 'A_1' of 1956 in its first year can be traced upto 'A_4' in its fourth year in 1959 and 'q_5' of 1956 in its fifth year can be traced upto 'q_8' in its eighth year in 1959, 'R_8' of 1956 in its eighth year can be traced to 'R_9' in its ninth year in 1958.

Sekharan (loc.cit.) has observed well-marked periodicity in the growth rates in the different months of a year in Rastrelliger canagurta. He has observed rapid growth during July-September and almost negligible growth during the months January-June. Bayliff (loc.cit.) has described rapid growth from January to March in Cetengraulis mysticus every year and nearly cessation of growth thereafter till next January. He has found these periods of accelerated growth corresponding to the annual period of upwelling.

However, in the present study such a comparative phenomenon of rapid, slow or cessation of growth in different months of a year has not been observed in P.heptadactylus. The fish shows a steady decrease in the rate of growth year after year till it reaches nine years.

Growth

Von Bertalanffy (1938) showed that the growth of a fish can best be expressed by the equation:

$$L_t = L_\infty \left(1 - e^{-K(t - t_0)} \right) \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

wherein

L_∞ = maximum or asymptotic length that a fish can theoretically reach,

K = slope or the coefficient of catabolism

and t_0 = time or age when the fish length is theoretically supposed to be zero,

are the growth parameters and

L_t = length of the fish at the age t.

Estimation of growth Parameters by Arithmatic Method

Von Bertalanffy's growth equation can be rewritten in the form:

$$L_{t+1} = L_{\infty}(1 - e^{-K}) + L_t \; e^{-K} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

which is a linear equation in terms of L_t and L_t+ 1 and used by Baganel (1955 a & b) in his study on the growth of long rough dab. This is the same as

$$L_{t+1} = a + bL_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where $a = L_{\infty}(1 - e^{-K})$ .... (4)

and $b = e^{-K}$ .... (5)

Applying the method of least squares (Snedecor, loc.cit) to 3 above, the constants L_{∞} and e^{-K} can be solved as shown below. for the following values of L_{t+1} and L_t in the age length data of P. heptadactylus.

	L_{t+1}	L_t
1.	128 mm	83 mm
2.	158 "	128 "
3.	188 "	158 "
4.	213 "	188 "
5.	237 "	213 "
6.	255 "	237 "
7.	273 "	255 "

Thus the estimated values of 'b' and 'a' are as follows:

$b = 0.8554 = e^{-K}$ and $a = 53.2$

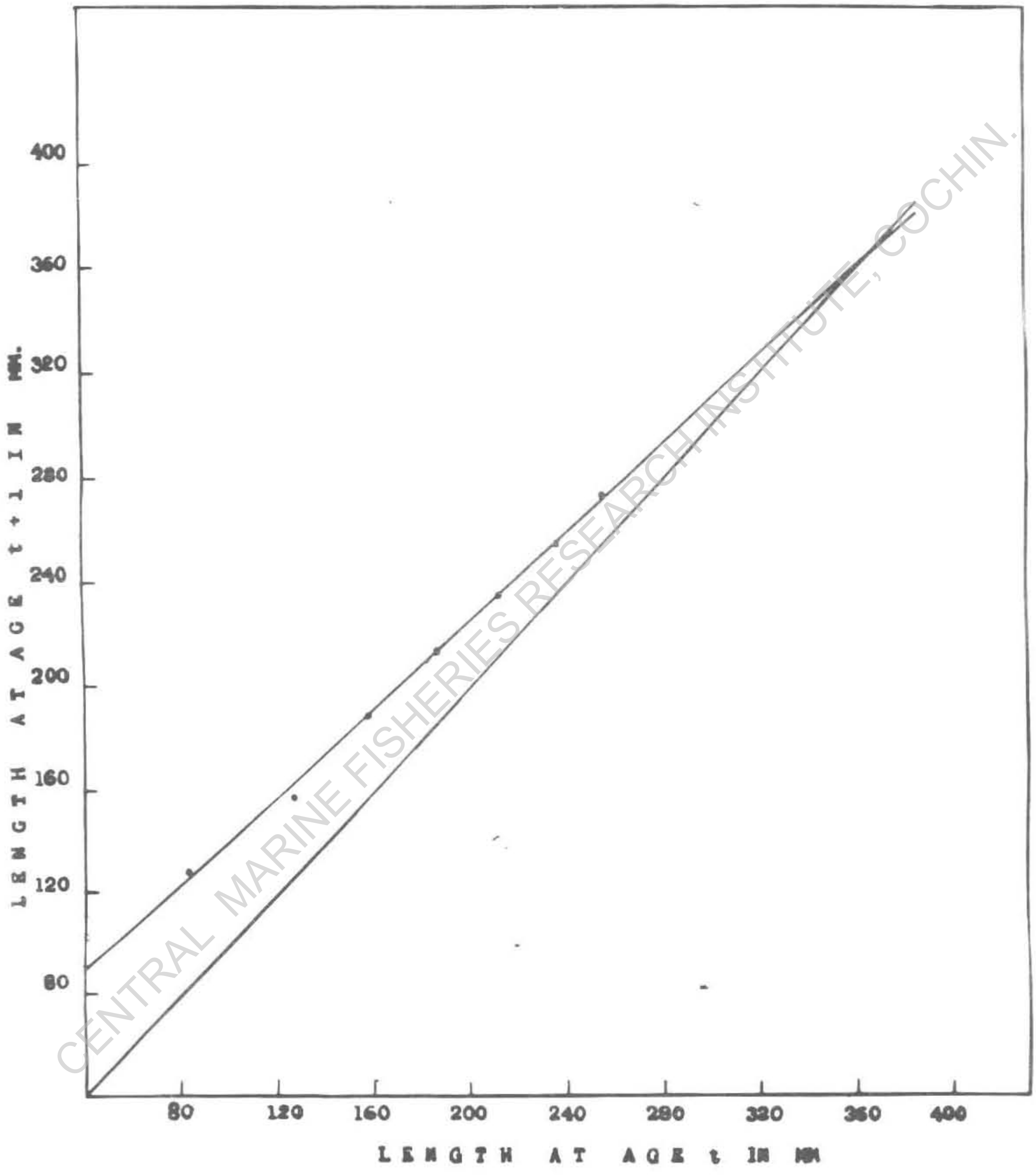
From the value of 'b' we can get the value of K from the formula

Table 12

Age-length data: values of t_0 at different ages

Age t	Length (mm) L_t	$L_\infty - L_t$	$\log_e (L_\infty - L_t)$	t_0
1	83	285	5.65249	-0.6279
2	128	240	5.48064	-0.7225
3	158	210	5.34711	-0.5730
4	188	180	5.19296	-0.5549
5	213	155	5.04343	-0.5073
6	237	131	4.87520	-0.5788
7	255	113	4.72739	-0.5203
8	273	95	4.55388	-0.6254
Average t_0				-0.5888

21. Walford's graph of length at age t + 1 against length at age t.



400
360
320
280
240
200
160
120
80
LENGTH AT AGE t + 1 IN MM.
80
120
160
200
240
280
320
360
400
LENGTH AT AGE t IN MM

$$K = \log_e \frac{1}{e^{-K}} = \log_e \frac{1}{0.8554}$$

$$= = \log_e 1.1690 = 0.1570.$$

Substituting the value of e^{-K} and 'a' in 4 we have

$$53.2 = L_\infty (1 - 0.8554)$$

Therefore $L_\infty = \frac{53.2}{1-0.8554}$ 367.91 mm

We can rewrite 1 as

$$t_o = \frac{1}{K} \left(\log_e L_\infty - \log_e (L_\infty - L_t) \right) - t \ .....(6)$$

Using 6 the average value of t_o calculated for different ages was found to be -0.5888 years (Table 12) for this species.

Thus the length equation 1 becomes

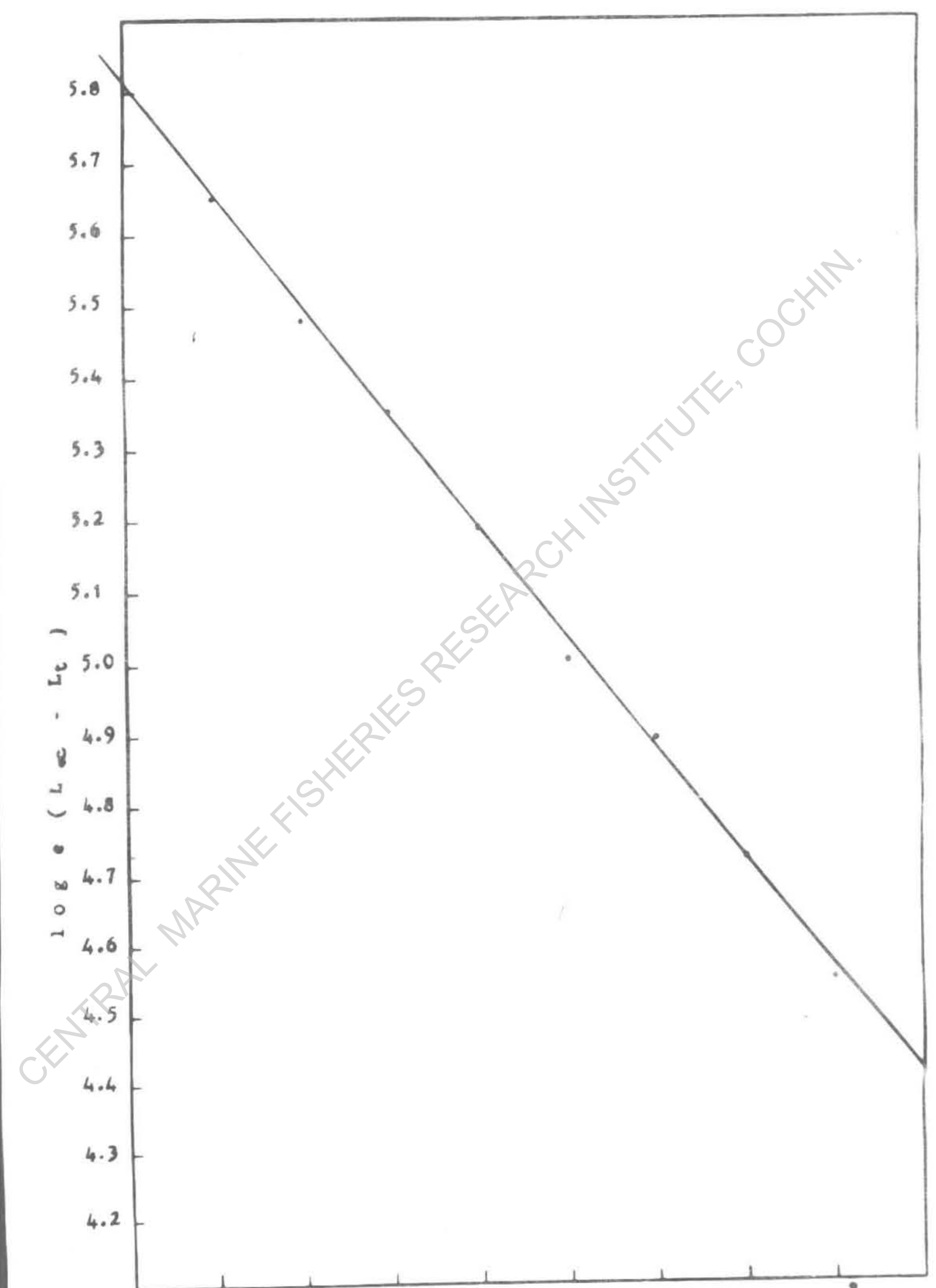
$$L_t = 368 \left(1 - e^{-0.1570 (t - (-0.59)} \right) \ .... (7)$$

Estimation of Growth Parameters by Graphical Method

Walford's method of obtaining the growth parameters by plotting L_t against L_{t+1} (Fig. 21) gave the value of L_∞ as 368 mm which is the point of interception of the growth line by the bisector. The slope of the growth line is equal to e^{-K} of equation 1 from which the value of K is found to be 0.1543.

The equation 6 shows that when the values of $\log_e (L_\infty - L_t)$ are plotted against the corresponding ages, a straight line is obtained (Fig. 22) whose Y intercept is equal to

22. Log e (L_{∞} - L_t) plotted against age for the Value L_{∞} = 388 mm.



5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
$\log_e (L_\infty - L_t)$
1
2
3
4
5
6
7
8
AGE IN YEARS

Table 13

Fit of von Bertalanffy's equation to length at age data for

<u>*P. heptadactylus*</u>

Age (t)	$t-t_o$	$-K(t-t_o)$ +	$e^{-K(t-t_o)}$	$1-e^{-K(t-t_o)}$	Theoretical length $L_\infty(1-e^{-K(t-t_o)})$	Observed length
1.	1.41 59	0.221370	0.802519	0.197481	73	83
2	2.41	0.378370	0.683861	0.316139	116	128
3	3.41	0.535370	0.582748	0.472520	154	158
4	4.41	0.692370	0.501576	0.498424	183	188
5	5.41	0.849370	0.427415	0.572585	211	213
6	6.41	1.003700	0.364219	0.635781	234	237
7	7.41	1.163370	0.313486	0.686514	253	255
8	8.41	1.320370	0.267135	0.732865	270	273

$\log_e L_\infty + Kt_0$.

In this case the value of interception on the Y-axis is 5.81. Therefore

$$t_0 = \frac{5.81 - 5.91}{0.1543} = - 0.63 \text{ years}$$

Thus 1 can be written as

$$L_t = 368 \left\{ 1 - e^{-0.1543 (t - (- 0.63) } \right\} \text{.........} (8)$$

which is almost the same as 7.

Using the equation 7 the theoretical values of L for given ages in P. *heptadactylus* were obtained and presented in Table 13. It can be seen that the differences between the observed and theoretical values is very small ranging between 2 mm and 5 mm excepting for the first two years, when also, the differences noticed are not very great being 10 mm and 12 mm.

Age Composition of Commercial Catch

An accurate knowledge of the age composition of commercial catches for successive years will help in the management of a fishery and in predicting the success or failure of the fisheries in the forthcoming years.

Method for calculating the age composition suggested by Hodgson (1939) for hearing, was made use of with some modifications by Fairbridge (1952) for flathead. The method used for flathead has been employed here for P. *heptadactylus*.

This method involves a number of calculations as described in the following lines.

(1)) Month-wise length frequency distribution was worked with 15 mm class intervals.

(2) From the knowledge of otolith and scale readings, the frequencies at each 15 mm group were divided into their age-groups.

(3) The mean weight of each 15 mm size-group was calculated from the observed weights.

(4) The frequencies in each 15 mm size-group were multiplied across by the corresponding weights and these products were summed up for each age-group. The summed products for each age-group added together gave the total for the month.

(5) The proportion of this to the total weight was calculated for each age-group.

(6) The monthly total landings obtained from the New India Fisheries log books were distributed in the same proportion amongst different age-groups.

(7) Dividing the calculated weight by the observed total weight for each age-group and then multiplying it by the number of fish in that age-group the actual number of fish belonging to that age-group in the commercial catch by the New India Fisheries bull-trawlers, was enumerated.

Table

Age composition of *P. heptadactylus* by weight and number of indivi-

Age-group	Size-group in mm.	Frequency	Mean weight in gm.	Weight for each size-group in gm.
II	106-120	4	23.4	93.6
	121-135	32	35.1	1,123.2
III	136-150	70	48.9	3,423.0
	151-165	88	66.5	5,852.0
IV	166-180	96	85.6	8,217.6
	181-195	68	112.5	7,650.0
V & above	196-210	45	144.7	6,511.5
	211-225	14	174.7	2,445.8
	226-240	11	227.3	2,500.3
	241-255	2	269.6	539.2
Total				

14

duals for March 1959 in the catch by New India Fisheries bull-trawlers.

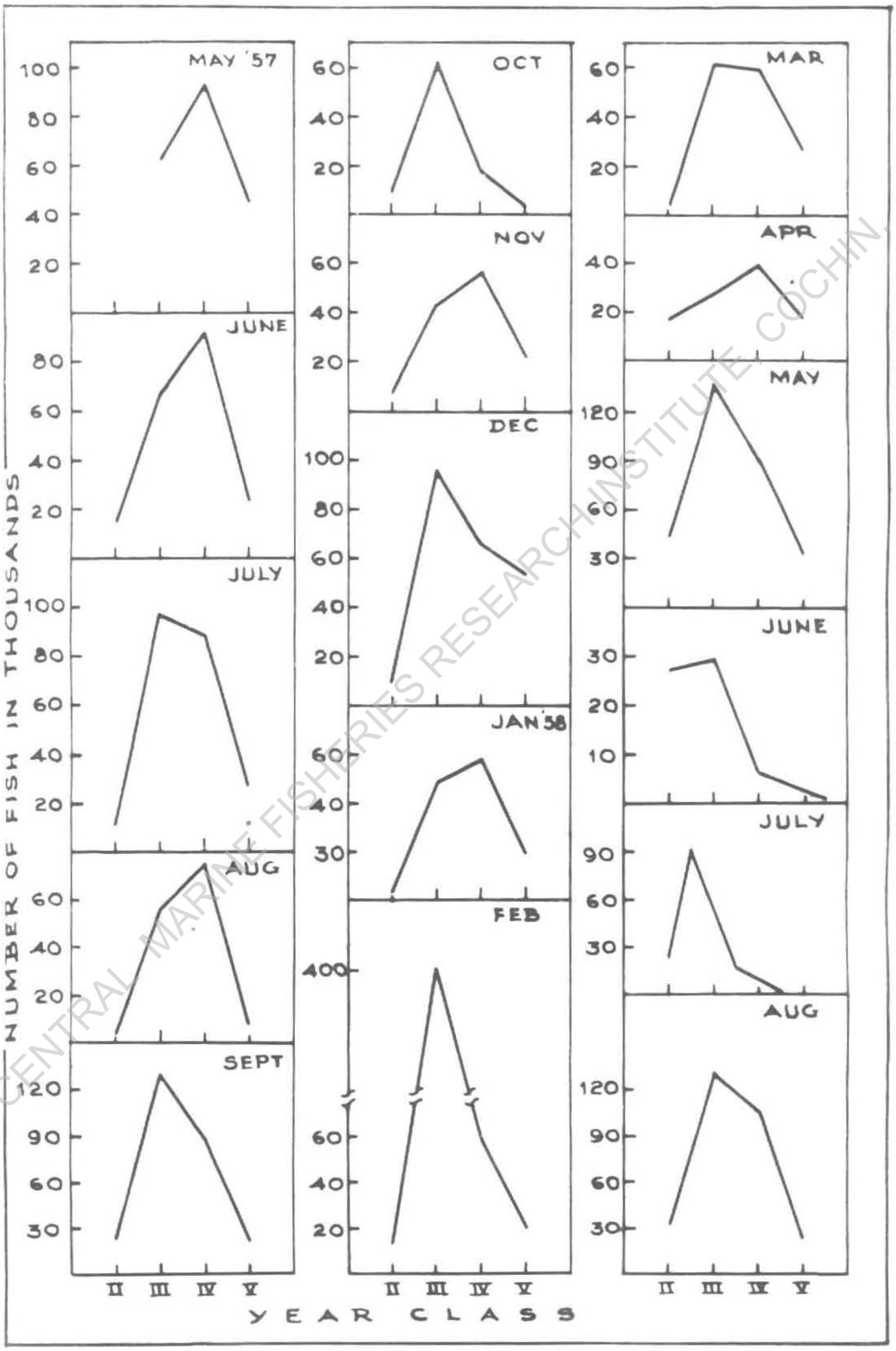
Sum of weights for year-group	% of sum of weights in the total	Weight in the total landings in gm.	Calculated number of fish
1,216.8	3	3,336,660.0	98,718
9,275.0	24	26,693,280.0	454,721
15,867.6	42	46,713,240.0	482,806
11,996.8	31	34,478.820.0	206,928
38,356.2		111,222,000.0	

(8) Summing up of these calculated weights and numbers in each age-group for twelve months gave the total for the year.

Calculations for the month of March 1959 carried out on the same lines are presented in Table 14. Similarly the data was analysed month-wise for the period May 1957 to April 1959. However, data for the months of December 1957 and May 1958 were not available. Thus the figures for these months were made up by calculating the average weights and numbers for eleven months in each of the two years.

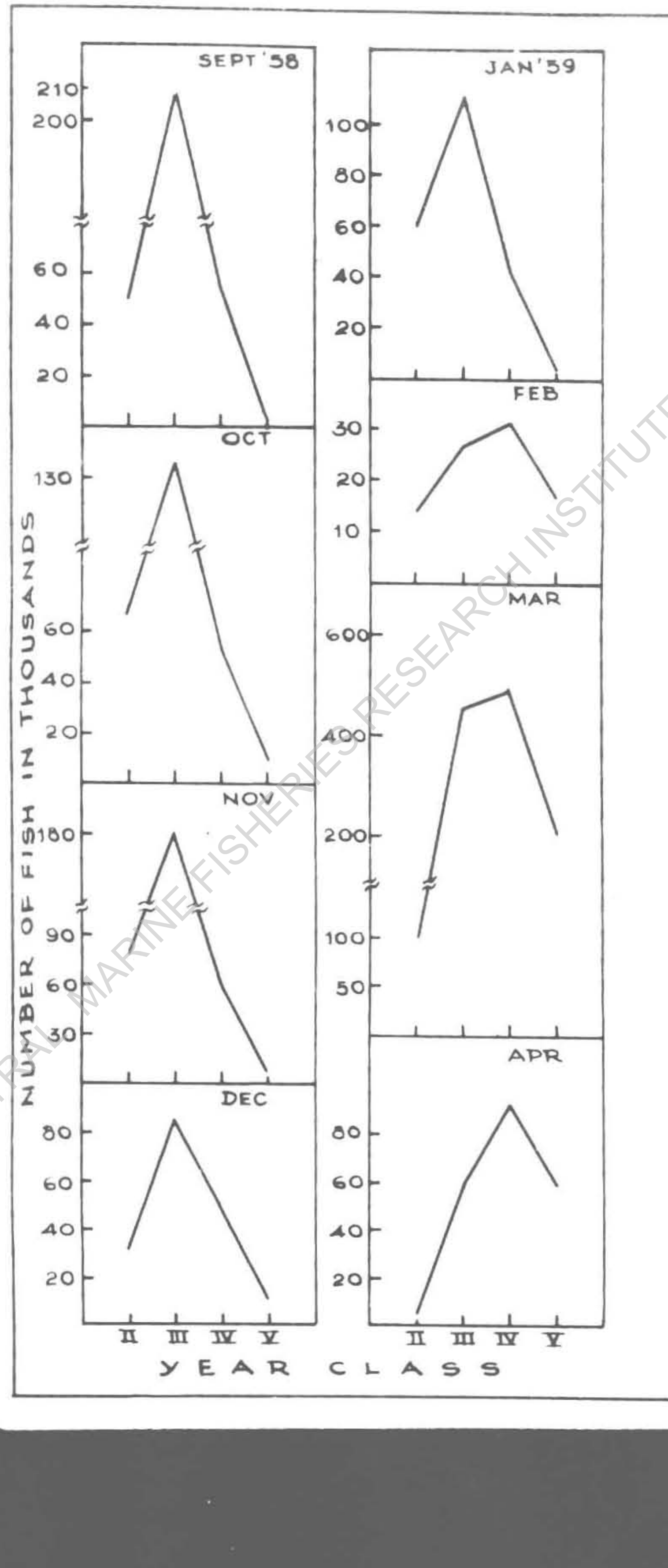
The accuracy of the analysis depends on the factors like correct landing data, the accurate age determination and the length-weight relationship. Regarding the landing data it can be said that the figures provided by the skippers of the New India Fisheries bull-trawlers are reliable excepting for the smaller sized fish not represented in the catch which may be due to the large mesh size at the cod end of the trawls. This may be the reason for the total absence of the first year-group and poor representation of the second year-group. The age determination studies can be said to be reliable inspite of scales being of no use in assessing the age of the lower size-groups, but at this point otoliths come to an aid with their well marked rings. It is even seen that there is no marked difference between the growth of the two sexes which may affect the magnitude of calculated numbers. The length-weight relationship in this fish remains fairly uniform throughout the year irrespective of the season and sex. The

22 a. Monthly age composition by numbers of _P. heptadactylus_ in the New India Fisheries trawl catch during May 19[illegible] to April 1959.



MAY '57
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN '58
FEB
MAR
APR
MAY
JUNE
JULY
AUG
NUMBER OF FISH IN THOUSANDS
YEAR CLASS
II
III
IV
V

23. b. Monthly age composition by numbers of P. heptadactylus in the New India Fisheries trawl catch during May 1957 to April 1959.


SEPT '58
OCT
NOV
DEC
JAN '59
FEB
MAR
APR
NUMBER OF FISH IN THOUSANDS
YEAR CLASS
II III IV V

results obtained and presented here can therefore be considered reliable.

The calculated number of fish in age-groups II to V and above for each month has been plotted in Figs. 23a & b. It is seen that throughout, the second age-group was poorly represented in the catch and as mentioned earlier it may be because of the incomplete sampling of the gear. The maximum of 78,283 fish of this age with an approximate weight of 2.6 metric tons were fished during November 1958 (Fig. 23b) while the minimum of 3,329 fish with an approximate weight of 0.1 metric tons during August 1957 (Fig.23a). The fish of V year and above age-groups together formed a meagre number in the catch and because of their lesser contribution to the commercial catch were pooled together and not subdivided into different age-groups. The maximum of 206,928 fish of these age-groups with an approximate weight of 3.4 metric tons were caught in March 1959 (Fig.23b) and the minimum of 628 with an approximate weight of 0.09 metric ton in June 1958 (Fig.23a). The III and IV year-groups contributed to the bulk of the catch. During March 1959 (Fig. 23b) III and IV year-groups were seen to yield the maximum number of 454,721 and 482,806 fish respectively with the corresponding weights of 26.7 and 46.7 metric tons. The monthly percentage of these two important year-groups together varied on an average from 60-90. From the commercial point of view, weight of the fish is important and from the recruitment point, the number of fish in different age-groups. The IV year-group was commercially

Table 15

Age-composition by number and weight of *P. heptadactylus* in the years 1957-58 and 1958-59 catch by the New India Fisheries bull-trawlers.

Age group	1957 - 58		1958 - 59	
	Number	Weight (M.T.)	Number	Weight (M.T.)
II	118,588	3.9	529,085	17.4
III	1,149,521	53.1	1,650,830	91.2
IV	795,758	76.5	1,073,319	102.5
V & above	252,919	42.1	370,838	54.1
All age-groups	2,316,786	175.6	3,624,072	265.1

important during most of the months in the first year of observation and it was the third year-group in the second year. The number of III and IV year-groups were more or less of equal importance because none of these two age-groups showed any sort of uniform dominance over the other. From Table 15 it is evident that all the year-groups are represented more by number as well as by weight in the second year of observation than in the first.

Since the catch data was not available for P.heptadactylus either from the 'Dol' net or otter trawl, the age composition was not workable for the catches from these two gears. However, from the length frequency studies it can be said that in the case of 'Dol' net samples, the I year-group dominated throughout the period of observations forming above 80%, whereas II and III year-groups varied from 2% to 12%. The IV year-group occurred only in stray numbers. The otter trawl catches also showed a high percentage of I year-group. The second year-group was better represented here than in the 'Dol' catch forming about 30%, and rest of the age-groups occurred in stray numbers.

MATURATION AND SPAWNING

It is essential to have a sound knowledge on some of the basic biological factors as maturation cycle, minimum size at first maturity, sex-ratio, spawning, fecundity, ponderal index etc. of fish species, for the management of their fisheries.

The approach of Clark (1934) to the study of maturity in California sardine (*Sardina caerulea*) by means of ova diameter measurements was the first of its kind in this field. Hickling and Ruthenberg (1936) have in similar manner determined the spawning periods in hake, haddock, pilchard and other fish. Important contributions to the fecundity studies were by Hickling (1940) on the herring of the Southern North Sea, MacGregor (1957) on Pacific sardine *Sardinops caerulea* and Bagenal (1957 & 1963) on long rough dab, *Hippoglossoides plastessoides* and plaice.

In recent years a good amount of work on the maturity and spawning behaviour of commercially important fishes of India, is available in the published accounts. Karandikar and Palekar (1950) have studied the ovaries of *Polynemus tetradactylus* in relation to its spawning habits. Palekar and Karandikar (1952a, 1952b and 1953) have worked on the maturity and spawning habits of *Thrissocles purava*, *Harpodon nehereus* and *Coilia dussumieri*. Pradhan and Palekar (1956) have described the stages of sexual maturity in *Rastrelliger canagurta*. Prabhu (1956) has given an account of the spawning periodicity in some of the marine teleosts along the east coast of India. Krishnamoorthi (1958) has made observations on the spawning season of Scomberomorous guttatus. Dharmamba (1959) has studied the maturation and spawning of some common clupeids of Lawson's Bay (Waltair). Qasim and Qayyum (1961) have studied the spawning frequencies and breeding seasons of some fresh water fishes in the plains of Northern India.

Studies by Mohamed (1955), Nayak (1959a) and Karekar and Bal (1960) on the maturity and spawning behaviour of Polydactylus indicus and Karandikar and Palekar (loclcit.) on the spawning periodicity of Polynemus tetradactylus are contributions of much significance in the comparative study on the maturation of different species of Polynemids. However, nothing is known about the maturity and breeding habits of Polynemus heptadactylus. Hence, the present investigation on the maturation, sex-ratio, spawning periodicity, fecundity and ponderal index of this species has been attempted.

Material and Methods

A total of 1,746 P.heptadactylus drawn from the various sources mentioned below during the period 1956-1959, were made use of in this study. Of these 520 specimens were examined from the inshore waters of Bombay and the remaining 1,226 from the offshore waters. 245 specimens from the inshore fish catches brought from Versova fish landing place were examined during December 1956 to November 1958 with the exclusion of some of the months when the fishing was totally absent during the monsoon period of June to September due to inclement weather. 275 specimens for this study during May 1956 to October 1958 were obtained from the landings of the Government of India fishing vessels operating in the waters off Bombay. The offshore catch was obtained from the New India Fisheries trawlers operating during May 1957 to October 1959.

While weekly collections from the inshore landings at Versova could be had regularly, the trawl collections were obtained either weekly or biweekly or even fortnightly depending on the arrivals of the trawlers at Sassoon Docks. Till June 1958 each sample consisted of 10 specimens taken at random, but, subsequently, the number was increased to 25. Specimens below 75 mm. in furcal length were rejected as sexes could not be differentiated.

When brought to the laboratory the fish were measured for furcal length and grouped into 12 size-groups with 15 mm. class intervals. After studying the condition of the ovary and the nature of the ova under the microscope, the maturity stages were recorded. A few ovaries in the advanced stage of development, were removed and preserved in 10% formalin for further studies on the ova diameter measurements and fecundity.

Reproductive Organs

A large percentage of P. heptadactylus is dioecious wherein the sexes are separate. Instances of monoceious nature also of this species is recorded by the author (Nayak, 1959b).

A pair of gonads is suspended laterally from the dorsal wall of the coelomic cavity either by the mesovarium or by the mesoarchium, beneath the mesonephros and the air bladder. A little before the posterior end, the gonads open to the exterior by a common duct through a common genital opening. Sexes could not be determined in specimens measuring less than 75 mm in furcal length.

Ovaries:- The paired ovaries are small and thread-like in the earlier stages, but increase in length, breadth and thickness with the advance in maturity. As the ovaries mature, they get distended due to the changes in the intra-ovarian eggs. They attain yellow colour as a result of yolk formation in the intra-ovarian eggs. The right and left ovaries extend posteriorly beyond the anus. Slightly in advance of the posterior ends, the two ovaries appear to have fused in the middle region from where the oviducts originate. The two oviducts join and open out through a very short common oviduct.

There is no significant asymmetry between the right and left ovaries. Very slight differences at times noticed in the length and breadth of these two may be due to minor errors while measuring or to the differential degrees at which the reproductive elements are discharged in batches. It may be stated here that a fish of 105 mm. in furcal length had its left ovary measuring 14 mm and the right one 15 mm in length, the breadth of both being 2 mm; a fish of 204 mm had both of its ovaries measuring 66 mm in length, but showed difference in their breadth, being 22 mm for the left and 17 mm for the right gonads. Occasionally, one of the ovaries was found to be lobulated in its anterior end.

On the inner surface of the ovaries, the germ cells of the ovigerous lamellae bear many a batch of oocytes in successive stages. The intra-ovarian eggs, as they mature, dehisce from the ovigerous lamellae and fall into the ovarian lumen. These eggs accumulated in the ovarian lumen and oviducts, are expelled out in batches.

<u>Testes</u>:- The testes are thin and filamentous in the earlier stages, but with the advancement of maturity, they get enlarged and attain whitish colour. The fully developed testes are slightly flat, fleshy, more solid and milky white in colour and when punctured, milt flows out of them.

Just as in ovaries, no asymmetry of significance has been noticed between the right and left testes. Slight differences noticed at times in the length and breadth of these two, may be due to the same reasons as mentioned in the case of ovaries. A male <u>P. heptadactylus</u> of 100 mm in furcal length had both of its testes measuring 10 mm in length and 2 mm in breadth; a fish of 130 mm had its left testis measuring 170 mm and right one 180 mm in length whereas both of them a breadth of 9 mm; another male of 162 mm in length recorded left testis measuring 46 mm and the right testis 50 mm in length with a breadth of 11 mm for the former and 12 mm for the latter.

Maturation

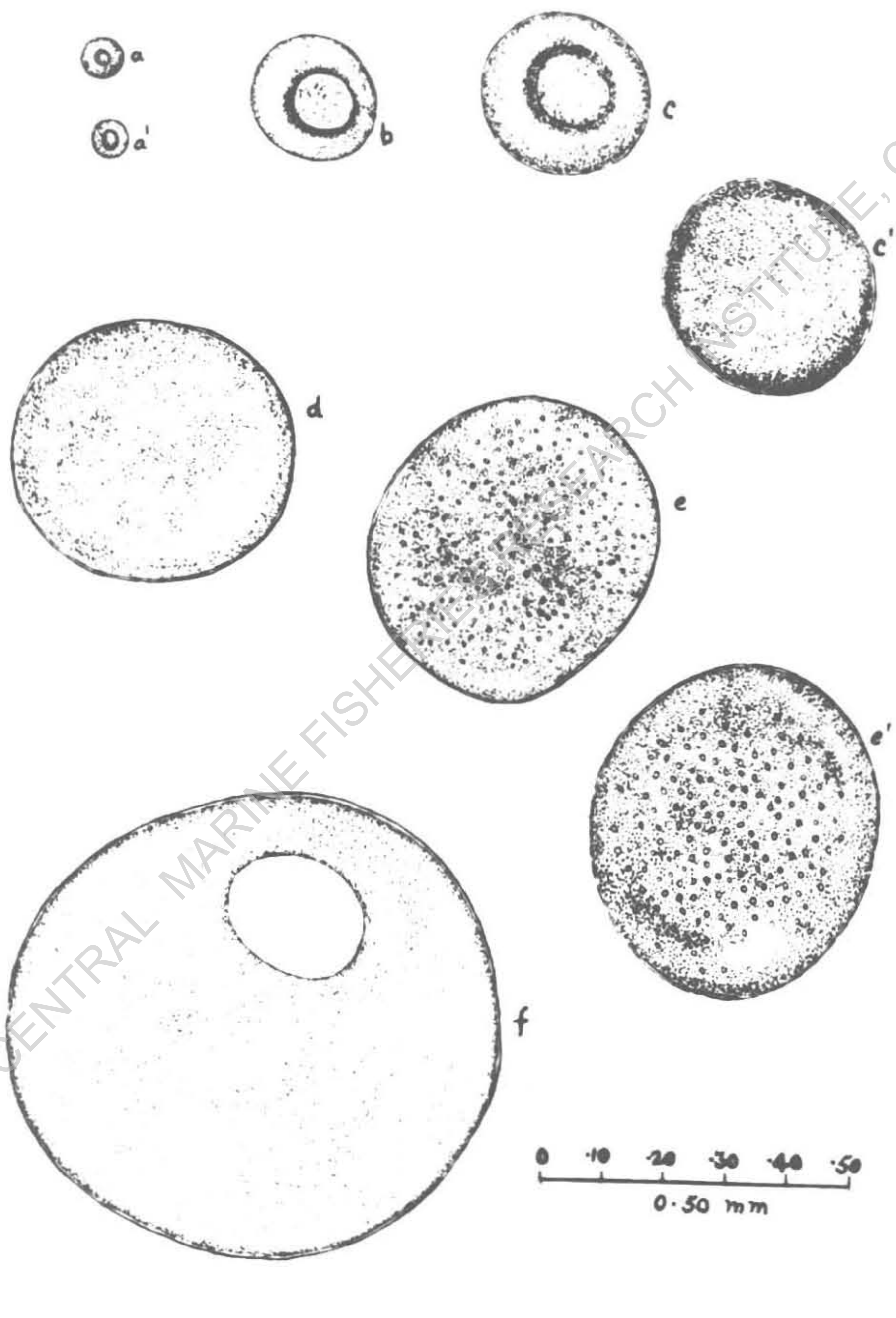
Growth of the ovary is said to begin from the posterior part near the vent and proceed anteriorly. This growth is accompanied by a series of changes in the size and appearance of the ovary and also in the details of the intra-ovarian eggs with respect to their size and yolk distribution. Accordingly, fish have been grouped into four major categories of 'Immature', 'Maturing', 'Mature' and 'Spent'. A fish has to undergo the first three stages before spawning and the last one indicates a post-spawning condition.

The ovary and ova of P. heptadactylus in different stages of maturity are described below (Fig. 24)

Immature fish:- The immature fish has a pair of small colourless thread-like ovaries, of varying thickness extending to less than half the length of the body cavity. Ova are invisible to the naked eye.

Under the microscope immature ova are almost rounded in appearance. They are minute yolkless and transparent with a single distinct nucleus in the centre and cytoplasm surrounding it. Ova measures upto 0.32 mm in diameter. The immature stage is further divided into two groups. The immature females include those which are yet to attain first sexual maturity and

24. Ova in different stages of maturity in *P. heptadactylus*: Stage I-a,a'; Stage II-b; Stage III-c,c'; Stage IV-d; Stage V-e,e'; Stage VI-f.


a
a'
b
c
c'
d
e
e'
f
0 ·10 ·20 ·30 ·40 ·50
0·50 mm

those which are recovering after spawning.

Maturing fish:- Maturing ovaries extend from half the length of the body cavity to completely filling it. The yolk begins to be deposited in the ova and the ovaries attain yellow colour.

Ova undergo a series of changes from being opaque due to the heavy deposition of yolk to getting translucent in the penultimate stage when the oil globules begin to appear. At this stage when the yolk deposition increases, the cytoplasm becomes transparent round the periphery. The ova diameters range from 0.33 mm to 0.64 mm. The maturing fish are subdivided into three groups.

Mature fish:- Mature ovaries fill the body-cavity to a very large extent and attain creamish colour. Ova are transparent or translucent with one to many oil globules when viewed under the magnification of a microscope. The oil globules measured from 0.2 mm to 0.3 mm in diameter. Ova diameters are found to range from 0.65 mm to 1.04 mm.

It may be of interest to note here that the mature ova of P. heptadactylus are of the nature of pelagic eggs as in the other two allied species, P. tetradactylus and P. indicus. Karandikar and Palekar (loc.cit.) observed oil globules ranging between 0.25 mm and 0.30 mm in diameter in the mature ripe ova of P. tetradactylus, ranging between 0.70 mm and 0.85 mm in diameter. However, the author had an opportunity to observe the ripe ova of the same species ranging between 0.70 mm and

1.00 mm in diameter. Nayak (1959 a.) recorded in P. indicus oil globules measuring between 0.26 mm and 0.40 mm in diameter in the ripe ova measuring between 0.63 mm and 1.10 mm. Thus it is seen that all these three species of Polynemids, though they differ greatly in the maximum size to which they grow, appear to have ripe ova of almost the same size and also the oil globules, one in each, of the same nature.

Spent fish:- Spent ovaries are blood shot in colour and shrunken in appearance. They are flaccid, empty and sac-like. They contain innumerable small immature yolkless ova along with a few degenrating residual ones in the process of resorption. After the resting period, the fish recovers and undergoes the maturation cycle of immature, maturing and mature stages.

Based on the external morphological characters of the ovary and on the microscopic structure of the ova along with their diameter measurements the following maturity key for the female P. heptadactylus has been drawn.

Immature - I : Ovary small, thread-like, colourless; ova invisible to the naked eye, under microscope yolkless and transparent with a single nucleus in the centre, measuring upto 0.16 mm in diameter (Fig. 24 a, a').

Immature - II : Ovary slightly thicker, less than half the length of the body-cavity, colourless; ova invisible to the naked eye, transparent with a nucleus in the centre, ranging between 0.17 mm to 0.32 mm in diameter (Fig. 24 b).

Maturing - III : Ovary nearly half the length of the body-cavity, yellow in appearance due to the deposition of yolk in the ova; ova visible to the naked eye, firmly held by interstitial tissue, getting opaque, ranging from 0.33 mm to 0.48 mm in diameter (Fig. 24c, c').

Maturing - IV : Ovary more than half the length of the body-cavity; ova opaque, completely filled with yolk with a transparent periphery, measuring from 0.49 mm to 0.56 mm in diameter (Fig. 24d).

Maturing - V : Ovary completely filling the body-cavity; ova opaque, fully laden with yolk, some getting translucent with many small oil globules from 0.57 mm to 0.64 mm in diameter (Fig. 24 e, e').

Mature VI : Ovary completely filling the body-cavity, somewhat creamish in colour; ova transparent with oil globules ranging from one to many in number in yellow transparent background, when only one, oil globule ranges from 0.2 mm to 0.3 mm in diameter; ova ranging from 0.65 mm to 1.04 mm in diameter; dehisced ova found in the lumen of the ovary (Fig. 24 f).

Spent - VII : Ovary shrunken, flaccid and reddish in colour; innumerable small immature ova with a few large degenerating residual ones.

The above seven maturity stages correspond to the standard maturity stages adopted by the International Council of the Exploration of the Seas (Wood, 1930).

Different maturity stages could not be assigned for males because these stages were not very distinct. The testes ripen early even when their full dimensions are not attained and continue to show ripe spermatozoa all through thereafter.

Maturity Stages in Commercial Catches

The different maturity stages appearing during different times in a year in the commercial catches of a species of fish help in tracing its breeding season and the breeding habits. Knowledge of this based on a study of samples from the inshore and offshore catches also throws light on the location of the probable breeding grounds of the fish. In the following account the maturity stages are treated separately for the inshore and offshore catches.

Maturity stages in the Inshore Catches

Of the 520 *P. heptadactylus* examined from the inshore catches, 394 were females. Tables 16 and 17 show the monthly percentages of maturity stages.

Table 16

Monthly percentage of different maturity stages of female *P. heptadactylus* in the Inshore catch

Month	Maturity Stages						
	I	II	III	IV	V	VI	VII
May 1956	-	39	13	30	-	-	18
October	43	4	3	37	13	-	-
November	22	-	7	71	-	-	-
December	42	-	-	25	33	-	-
January 1957	67	-	-	22	11	-	-
February	70	18	-	6	6	-	-
March	88	12	-	-	-	-	-
April	57	40	3	-	-	-	-
May	47	47	-	-	-	-	6
June	40	20	10	10	-	-	20
September	70	25	-	5	-	-	-
December	17	55	11	17	-	-	-
October	38	62	-	-	-	-	-
January 1958	19	25	25	31	-	-	-
February	28	10	24	24	4	10	-
March	21	13	4	21	8	29	4
October	30	23	4	2	27	7	7
November	44	34	-	3	8	8	3

Table

Monthly percentage of different maturity stages of female

Size-group (Mid-point mm)	Maturity Stage	M			O			N	
		May 1956	Oct.	Nov.	Dec.	Jan. 1957	Feb.	Mar.	Ap
83	I	-	-	-	100	-	100	100	-
98	I	-	100	100	100	100	100	100	10
	II	-	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-	-
113	I	-	100	33	100	100	50	100	5
	II	-	-	-	-	-	50	-	5
	III	-	-	-	-	-	-	-	-
	IV	-	-	67	-	-	-	-	-
	V	-	-	-	-	-	-	-	-
	VI	-	-	-	-	-	-	-	-
	VII	-	-	-	-	-	-	-	-
128	I	-	-	-	-	-	-	-	5
	II	100	34	--	-	-	-	100	5
	III	-	33	-	-	-	-	-	-
	IV	-	33	100	50	-	-	-	-
	V	-	-	-	50	100	-	-	-
	VI	-	-	-	-	-	-	-	-

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.heptadactylus at 15 mm length-groups in the Inshore Catch.

		T		H		S			
ay	June	Sept.	Oct.	Dec.	Jan. 1958	Feb.	Mar.	Oct.	Nov.
	-	100	-	100	-	-	100	100	100
00	100	100	100	100	100	100	-	67	41
	-	-	-	-	-	-	-	33	53
	-	-	-	-	-	-	-	-	6
00	100	87	50	20	-	80	100	7	20
	-	13	50	80	100	-	-	33	60
	-	-	-	-	-	20	-	7	-
	-	-	-	-	-	-	-	7	-
	-	-	-	-	-	-	-	7	-
	-	-	-	-	-	-	-	13	20
	-	-	-	-	-	-	-	26	-
38	-	67	-	-	-	-	34	10	-
52	50	33	100	86	75	-	33	30	-
	50	-	-	14	25	50	-	-	-
	-	-	-	-	-	25	-	-	-
	-	-	-	-	-	25	-	40	100
	-	-	-	-	-	-	33	20	-

contd...

Table 17 contd..

Size-group (Mid-point mm)	Maturity Stage	M				O			N
		May 1956	Oct.	Nov.	Dec.	Jan. 1957	Feb.	Mar.	Ap
143	I	-	-	-	-	-	-	-	-
	II	67	-	-	-	-	100	-	10
	III	-	-	-	-	-	-	-	-
	IV	-	80	100	-	100	-	-	-
	V	-	20	-	100	-	-	-	-
	VI	-	-	-	-	-	-	-	-
	VII	33	-	-	-	-	-	-	-
158	II	50	-	-	-	-	-	-	-
	III	20	-	50	-	-	-	-	-
	IV	20	100	50	67	-	-	-	-
	V	-	-	-	33	-	100	-	-
	VI	-	-	-	-	-	-	-	-
	VII	10	-	-	-	-	-	-	-
173	I	-	-	-	-	-	-	-	-
	II	-	-	-	-	-	-	-	-
	III	20	-	-	-	-	-	-	10
	IV	60	-	100	-	-	100	-	-
	V	-	100	-	-	-	-	-	-
	VI	-	-	-	-	-	-	-	-
	VII	20	-	-	-	-	-	-	-

		T			H		S		
ay	June	Sept.	Oct.	Dec.	Jan. 1958	Feb.	Mar.	Oct.	Nov
	-	50	-	-	-	-	-	-	-
00	25	50	100	80	-	12	22	-	25
	-	-	-	-	67	22	-	13	-
	25	-	-	20	33	55	44	-	25
	-	-	-	-	-	-	12	87	25
	-	-	-	-	-	11	11	-	-
	50	-	-	-	-	-	11	-	25
	-	-	-	25	-	25	-	-	-
	-	-	-	25	-	25	-	-	-
	-	-	-	50	100	25	-	-	-
	-	-	-	-	-	-	-	100	-
	-	-	-	-	-	25	-	-	100
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	25	-	-	-
	-	50	-	-	-	25	-	-	-
	-	-	-	-	100	25	-	-	-
	-	50	-	100	-	-	-	-	-
	-	-	-	-	-	-	33	-	-
	-	-	-	-	-	25	67	-	100
	-	-	-	-	-	-	-	-	-

contd..

Table 17 contd..

Size-group (Mid-point mm)	Maturity Stage		M			O			N
		May 1956	Oct.	Nov.	Dec.	Jan. 1957	Feb.	Mar.	Ap
188	III	-	-	-	-	-	-	-	-
	IV	-	-	100	-	-	-	-	-
	V	-	-	-	-	-	-	-	-
	VI	-	-	-	-	-	-	-	-
	VII	100	-	-	-	-	-	-	-
203	IV	100	100	100	-	-	-	-	-
	V	-	-	-	100	-	-	-	-
218	IV	-	-	100	-	-	-	-	-
	VI	-	-	-	-	-	-	-	-

		T			H		S		
May	June	Sept.	Oct.	Dec.	Jan. 1958	Feb.	Mar.	Oct.	Nov.
-	-	-	-	-	-	-	25	-	-
-	-	-	-	-	100	-	25	-	-
-	-	-	-	-	-	-	-	100	-
-	-	-	-	-	-	-	50	-	-
100	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	100	-	-

Stage I: This immature stage appeared in the inshore catch all round the year usually in very high percentages which ranged between 17 in December 1957 and 88 in March 1957. It formed above 50% from January to April and also in September 1957.

Most of the fish in this stage were observed to be below 113 mm in furcal length in a number of months under observation. The percentages of this stage are observed to drop down from the length 128 mm onwards till 173 mm and the number of months in which this stage appeared in them was also small.

Stage II:- This stage, also an immature one, was noticed throughout the period of observation excepting in the three months of November 1956 to January 1957. The percentages ranged between 4 in October 1956 and 62 in October 1957. In May 1956, April, May and December 1957 and November 1958 the percentages were high being 39, 40, 47, 55 and 34 respectively. The immature stages I and II together formed above 60% in most of the months in the fish from inshore catches.

Stage II did not appear in fish below 98 mm in length and in all above that size upto 143 mm length its percentage of occurrence steadily increased. Its percentages were dropping down in fish between 143 mm and 173 mm in length.

Stage III:- This early maturing stage did not appear all through but only in certain months. It was absent in December 1956 to March 1957, May, September and October 1957 and November

1958. The monthly percentage range in which it occurred was small being 3% in October 1956 and April 1957 and 25% in January 1958. It appeared in fairly good percentages of 13 in May 1956, 10 in June 1957, 11 in December 1957 and 24 in February 1958.

It first started appearing in fish of 113 mm in length in small percentages. In the next higher four length groups the percentages were fairly good. In fish of 188 mm in length it formed 25% in March 1958.

<u>Stage IV</u>:- Excepting March to May and October 1957 this maturing stage appeared in all the months under observation with the percentages ranging between 2 in October 1958 and 71 in November 1956. It appeared in high percentages in May 1956, October 1956 to January 1957 and December 1957 to March 1958.

<u>Stage V</u>:- This stage, also a maturing one, appeared in the inshore catches in the eight months of October and December 1956, January and February 1957 and February, March, October and November 1958 in percentages ranging between 4 and 33. High percentages of 13, 33, 11 and 27 were observed in October and December 1956, January 1957 and October 1958 respectively. In sizes ranging between 98 mm and 203 mm it occurred in good percentages in different months.

<u>Stage VI</u>:- This ripe or mature stage met within the spawners was noticed in the inshore catches in the months of February, March, October and November 1958 only. The percentages ranged

Table 18

Monthly percentage of different maturity stages of female *P.heptadactylus* in the Offshore catch

Month	Maturity Stages						
	I	II	III	IV	V	VI	VII
May 1957	-	-	-	20	-	40	40
June	-	-	-	6	-	-	94
July	-	24	16	20	16	20	4
August	-	-	-	29	50	21	-
September	-	-	14	52	29	5	-
October	-	-	-	-	50	50	-
November	-	-	13	50	-	37	-
January 1958	-	-	4	42	54	-	-
February	-	-	4	45	23	23	5
March	-	-	-	17	33	33	17
June	-	-	22	11	22	11	34
July	-	-	-	24	35	39	2
August	-	-	-	57	14	29	-
September	-	-	-	13	13	7	67
October	-	-	-	25	39	6	30
November	-	10	-	33	-	-	57
December	14	-	-	39	11	6	30
January 1959	-	4	-	34	50	8	4
February	-	-	-	67	8	5	20

contd...

Table 18 (contd...)

Month	Maturity Stages						
	I	II	III	IV	V	VI	VII
March	-	-	-	51	-	9	40
April	-	-	-	66	6	11	17
May	-	-	-	50	-	-	50
June	-	38	-	8	4	-	50
July	-	-	-	70	13	-	17
August	-	-	-	43	3	-	54
September	-	-	-	60	5	-	35
October	-	4	-	40	4	-	52

Table

Monthly percentages of different maturity stages of femal

Size-group (Mid-point mm.)	Maturity Stage	M				O				N		
		May 1957	June	July	Aug.	Sept.	Oct.	Nov.	Jan. 1958	Feb.	Mar.	Ju
98	I	-	-	-	-	-	-	-	-	-	-	-
113	I	-	-	-	-	-	-	-	-	-	-	-
	II	-	-	100	-	-	-	-	-	-	-	-
128	I	-	-	-	-	-	-	-	-	-	-	-
	II	-	-	100	-	-	-	-	-	-	-	-
	IV	-	-	-	100	100	-	-	-	-	-	-
	V	-	100	-	-	-	-	-	-	-	-	-
	VII	-	-	-	-	-	-	-	-	-	-	-
143	I	-	-	-	-	-	-	-	-	-	-	-
	II	-	-	67	-	-	-	-	-	-	-	-
	III	-	-	-	-	34	-	-	-	-	-	[illegible]
	IV	-	-	-	-	-	-	-	-	100	-	-
	V	-	-	33	100	33	-	-	100	-	-	-
	VI	-	-	-	-	33	-	100	-	20	-	-
	VII	-	-	-	-	-	-	-	-	-	-	[illegible]
158	II	-	-	20	-	-	-	-	-	-	-	-
	III	-	-	60	-	50	-	-	20	-	-	-
	IV	-	-	-	34	50	-	-	40	20	-	-
	V	-	-	20	33	-	100	-	40	60	50	[illegible]
	VI	-	-	-	33	-	-	-	-	20	50	[illegible]
	VII	-	100	-	-	-	-	-	-	-	-	[illegible]

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P. heptadactylus at 15 mm. length-groups in the offshore catch

				T				H				S			
July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1959	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.
-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-
-	-	-	-	100	-	-	-	-	-	-	100	-	-	-	-
-	100	-	-	-	20	-	-	-	-	-	-	100	75	100	-
-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	50	-	40	100	100	-	-	-	-	-	25	-	-
-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	14	-	-	-	-	-	-	100	-	-	-	-
17	60	17	75	43	50	100	-	-	-	-	-	60	38	33	-
50	40	-	13	-	-	-	-	-	-	-	-	20	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	83	12	43	-	-	100	-	-	-	-	20	62	67	100
-	-	-	-	-	-	10	-	-	-	-	37	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	43	14	-	17	11	40	75	33	-	-	-	78	67	25	50
32	14	18	20	-	11	50	-	-	-	-	-	11	11	-	-
31	43	4	20	-	-	-	-	-	-	-	-	-	-	-	-
5	-	64	60	83	78	-	25	67	-	-	63	11	22	75	50

Table

Size-group (Mid-point mm.)	Maturity Stage	M					O				N	
		May 1957	June	July	Aug.	Sept.	Oct.	Nov.	Jan. 1958	Feb.	Mar.	Ju
173	II	-	-	-	-	-	-	-	-	-	-	-
	III	-	-	20	-	-	-	34	-	14	-	3
	IV	-	-	-	33	67	-	33	75	43	-	3
	V	-	-	-	67	33	100	-	25	14	100	-
	VI	-	-	60	-	-	-	33	-	29	-	-
	VII	100	100	20	-	-	-	-	-	-	-	3
188	II	-	-	-	-	-	-	-	-	-	-	-
	IV	--	-	50	25	50	-	-	20	67	25	-
	V	-	-	50	50	50	-	-	80	33	-	-
	VI	50	-	-	25	-	100	-	-	-	25	-
	VII	50	100	-	-	-	-	-	-	-	50	-
203	II	-	-	-	-	-	-	-	-	-	-	-
	III	-	-	-	-	50	-	-	-	-	-	-
	IV	-	50	50	-	-	-	-	33	34	20	-
	V	-	-	25	-	50	50	-	67	-	40	-
	VI	-	-	25	-	-	50	-	-	33	40	-
	VII	-	50	-	-	-	-	-	-	33	-	-
218	IV	-	-	100	-	80	-	100	33	100	-	-
	V	-	-	-	50	20	-	-	67	-	-	-
	VI	100	-	-	50	-	100	-	-	-	-	-
	VII	-	100	-	-	-	-	-	-	-	-	-

Contd..

				T				H				S			
ly	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1959	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct
-	-	-	-	11	-	-	-	-	-	-	16	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	52	12	27	22	75	33	100	67	67	50	17	57	33	58	42
40	16	19	33	-	-	67	-	-	-	-	17	14	-	-	8
40	32	13	7	-	25	-	-	-	-	-	-	-	-	-	-
-	-	56	33	67	-	-	-	33	33	50	50	29	67	42	50
-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-
20	83	-	-	50	71	33	63	36	69	33	20	100	20	67	50
40	-	-	64	-	15	-	12	-	8	-	-	-	-	22	-
40	17	11	9	-	-	67	6	28	8	-	-	-	-	-	-
-	-	89	27	50	14	-	19	36	15	67	60	-	80	11	50
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	86	50	40	67	50	-	87	60	89	50	-	-	-	86	50
-	-	-	40	-	25	100	-	-	-	-	-	-	-	-	-
00	14	-	-	-	-	-	-	-	11	-	-	-	-	-	-
-	-	50	20	33	25	-	13	40	-	50	100	-	100	14	-
-	-	-	-	-	-	-	100	100	50	67	-	-	-	100	-
-	-	-	100	-	50	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	50	-	-	-	25	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	25	33	-	-	-	-	-

Table

Size-group (Mid-point mm.)	Maturity Stage		M				O				N
		May 1957	June	July	Aug.	Sept.	Oct.	Nov.	Jan. 1958	Feb.	Mar.
233	IV	100	-	-	-	-	-	100	50	-	-
	V	-	-	-	-	-	-	-	50	-	-
	VI	-	-	100	-	-	-	-	-	-	-
248	IV	-	-	-	-	-	-	50	100	-	-
	VI	-	-	-	-	-	-	50	-	100	-

19 contd..

				T				H				S			
July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 1959	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.
-	-	-	-	-	100	-	-	100	-	-	-	-	-	-	-
-	-	-	-	-	-	100	100	-	50	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-
-	-	-	-	-	-	-	50	-	-	-	-	-	-	100	-
-	-	-	-	-	-	-	50	100	100	-	-	-	-	-	-

between 7 in October and 29 in March. The sizes at which this stage appeared varied from 113 mm to 218 mm.

Stage VII:- This post-spawning or spent stage appeared in May 1956, May and June 1957, March, October and November 1958. It formed 18% and 20% in the months May 1956 and June 1957. In October 1958, this stage formed 7% in the inshore catch. It was noticed at sizes ranging from 113 mm to 188 mm in the samples examined.

Maturity Stages in the Offshore Catches

Of the 1,226 fish examined from this source, 755 were females. Tables 18 and 19 show the monthly percentage of maturity stages.

Stage I:- This immature stage which predominated in the inshore catch throughout the year in high percentages, appeared only in December 1958 in the offshore catch giving a percentage value of 14. This stage was not well represented here and it may be due to the fact that fish below 98 mm were not available in the catch. It occurred in sizes ranging from 98 mm to 143 mm.

Stage II:- This immature stage like the previous one and unlike that in the inshore catch, was noticed in the offshore catch during July 1957, November 1958, January, June and October 1959 only. The maximum of 38% was recorded in June 1959 and the next high percentage of 24 was in July 1957. In November 1958 it formed 10%. In sizes ranging between 113 mm and 203 mm this stage appeared in fairly good percentage. This stage in higher lengths was met with generally in the spent recovering ones.

Stage III:- It is seen that this maturing stage occurred in the months of July, September and November 1957 and January, February and June 1958 only. It appeared in fairly high percentages of 16 in July, 14 in September and 13 in November of 1957 and 22 in June 1958 in sizes ranging from 143 mm to 203 mm.

Stage IV:- From this stage onwards, the pattern of distribution of the advanced stages changed in the offshore catch from that of the inshore catch because they occurred in higher percentages in the former. It occurred in very good percentages all along the period of observation excepting in October 1957. Though the percentages varied between 6 in June 1957 and 70 in July 1959, generally the percentages were above 33 in different months. It was noticed that this stage formed 50% and above in September and November 1957, August 1958 and February to May, July and September 1959 in sizes ranging between 128 mm and 248 mm in furcal length.

Stage V:- It is seen that but for the 6 months of May, June and November 1957, November 1958 and March and May 1959, this stage was noticed in fairly high percentages in almost all the months under observation in sizes ranging between 128 mm and 233 mm. The monthly percentages ranged between 3 in August 1959 and 54 in January 1958. It occurred above 20% during August to October of

1957, January to July and October of 1958 and January 1959.

Stage VI:- This stage appeared in all the months excepting June 1957, January and November 1958 and from May to October 1959. Its percentages ranged between 5 in September 1957 and February 1959 and 50 in October 1957. It was noticed to form 20% and above in the offshore catch during May, July, August, October and November 1957, February, March, July and August 1958 in fish of all lengths above 143 mm.

Stage VII:- But for the months August to November 1957, January and August 1958, this stage appeared in the catch all through, forming very high percentages during certain months. The percentages ranged between 2 in July 1958 and 94 in June 1957. In most of the months it formed 30% or more in the offshore catch, viz. May and June 1957, June and September to December 1958, March, May, June and August to October 1959 in fish above 128 mm.

From the foregoing account it is observed that all of the maturity stages appeared in almost all the size-groups, excepting those in which the fish had not attained sexual maturity. A fish attaining its first maturity passes through various maturity stages described earlier before it spawns and becomes spent. After the resting period, the spent fish recovers and the maturation cycle is repeated, for which reason all the maturity stages are noticed in the catch in almost all the length groups.

In the inshore catch the immature stages were noticed in very high percentages throughout the year and in the offshore catch, the advanced and spent stages. Though comparatively smaller in number, the mature stage in the inshore catch predominated in March. In the offshore catch this stage predominated in October and May. Spent individuals occurred throughout the year, but in general, both in the inshore and offshore catches, this stage appeared in very high percentages during March-June and August-November.

Thus the presence of all stages all the year round indicates that the spawning may be throughout the year. But as most of the stages show two periods of high percentages in their occurrence in a year, it appears that there are two peak spawning periods. i.e. about March - June and August - November. The presence of mature and spent individuals in the inshore and offshore catches, indicates that the spawning may be in both the waters. From the differences noticed in the percentages of advanced and mature stages, it may be inferred that the intensity of spawning is greater in the offshore waters than in the inshore waters. The occurrence of immature fish in very high percentages in the inshore catch may probably be due to their entering the inshore waters where they may be spending their earlier juvenile stages of life, after which the majority of them go back to the offshore waters for breeding.

Size at First Maturity

A total of 914 female *P. heptadactylus* from inshore and offshore catches were examined for determining the size at first maturity. All fish above stage III in which the ova are seen beginning to mature, are considered to spawn during the season. Hickling (1930) and Clark (1934) have indicated that there is a possibility of some error in following this method because eggs in adolescent fish may start to mature, but may fail to reach ripe stage and thus degenerate. However, it is observed that in *P. heptadactylus* maturing ova are noticed in most of the length groups throughout the year.

Table 20 shows the numbers and percentages of immature and mature fish in each of the 5 mm length groups. It is seen that in fish as small as 103 mm ~~formed~~ 4% were mature; in fish at 128 mm 42% and in those at 133 mm 48%. Practically all fish above 168 mm were mature.

From the data in Fig. 25 it is obvious that nearly 50% of the fish are mature when they attain a length of 133 mm. This is further supported by the study on the ponderal index in which the condition for the females was found to drop at a length of 133 mm and this may be attributed to the onset of sexual maturity. Thus it can be said that the female *P. heptadactylus* normally matures at 133 mm when it just completes its second year of life and enters the third year.

The only evidence to indicate the size at first maturity

25. Maturity curve of females of P. heptadactylus.

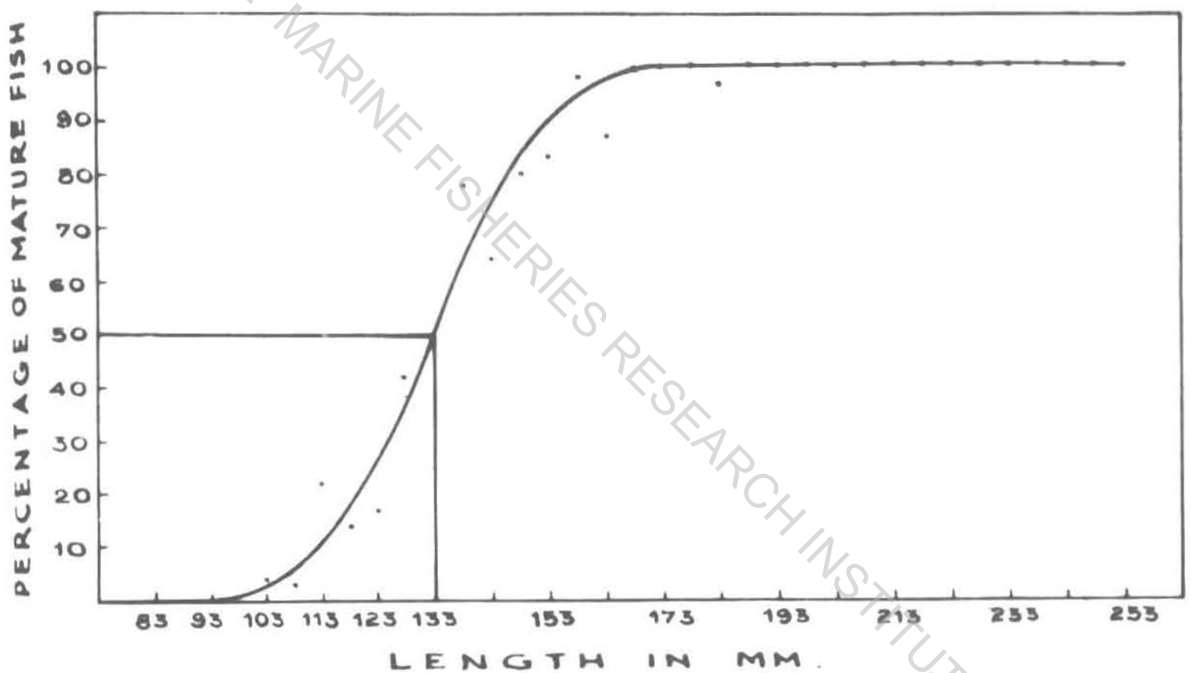

PERCENTAGE OF MATURE FISH
100
90
80
70
60
50
40
30
20
10
83
93
103
113
123
133
153
173
193
213
233
253
LENGTH IN MM.

Table 20

Number and percentage of mature female *P. heptadactylus* in 5 mm length-groups.

Size-group (Mid-point mm)	Total Number of fish	Mature fish	
		Number	Percentage
83	27	-	-
88	8	-	-
93	23	-	-
98	27	-	-
103	25	1	4
108	33	1	3
113	23	5	22
118	21	3	14
123	30	5	17
128	26	11	42
133	39	19	48
138	41	32	78
143	33	21	64
148	41	33	80
153	42	35	83
158	56	54	98
163	60	52	87
168	44	44	100
173	43	43	100

Table 20 (contd..)

Size-group (Mid-point mm)	Total Number of fish	Mature fish	
		Number	Percentage
178	56	56	100
183	35	34	97
188	32	32	100
193	30	30	100
198	22	22	100
203	21	21	100
208	28	28	100
213	9	9	100
218	13	13	100
223	8	8	100
228	3	3	100
233	6	6	100
238	2	2	100
243	3	3	100
248	1	1	100
253	3	3	100
Total	914	630	---

in the present study for males, is the condition factor which was found to drop at 128 mm which may be the size for the onset of maturity. The male *P. heptadactylus* appears to attain first sexual maturity at 128 mm when it just completes its second year of life.

Sex Ratio

There are no external characters by means of which the sexes in *P. heptadactylus* can be differentiated. The sexes were therefore, noted directly after opening the body-cavity. Sex of the fish below 70-80 mm could not be recognised even with the aid of a microscope. Females were distinguishable beyond this length due to the presence of oocytes but males with distinct reproductive elements, only after 90 mm in length. However, it may be mentioned here that hermaphrodite specimens were first noted in October 1958 and it was only after this they were treated separately. Superficial examination of an ovotestis reveals at first sight the well developed ovarian part and not the less developed testicular part for which reason, the gonad is often mistaken for an ovary. Fish in which sexes were indeterminate and which were available throughout the year were excluded from this study. A total of 1,601 fish, of which 503 were from the inshore catch and the remaining 1,098 from the offshore catch, were examined for this study.

In Table 21, the males and females of the inshore and offshore catches are pooled together and the percentage frequency

Table 21

Percentages of male and female *P. heptadactylus* at different lengths in 15 mm length-groups.

Size-group (Mid-point mm.)	83	98	113	128	143	158	173	188	203	218	233	248
No. of fish	35	99	140	213	267	296	239	161	95	35	10	11
Male (%)	6	22	39	54	46	31	14	4	3	0	0	0
Female (%)	94	78	61	46	54	69	86	96	97	100	100	100

of occurrence of the two sexes is shown at 15 mm class intefvals. It is observed that the proportion in which the two sexes appeared in the commercial catches, varied greatly with the length of the fish. Excepting at the length 128 mm, the females dominated in all other length groups. Males formed a very small percent of 6 in 83 mm length group. Their percentages started increasing with the length to 54 when they were of 128 mm in furcal length. After this, the percentage of males in the catch started falling down till the fish length of 203 mm when it formed 3%. Males were not encountered in the catches after the length of 203 mm. Conversely, the females predominated at all the lengths excepting at 128 mm length group in which they formed 46%. They occurred in very high percentage of 94 at 83 mm of length. Thereafter the percentages decreased in females till 128 mm and started rising up again. Beyond the length of 203 mm all were females. At no length the males and females appeared in 1:1 ratio in the catch.

Sex compsotion in the inshore catch from May 1956 to November 1958 presented in Table 22 shows that females dominated in the inshore catch throughout the period of observation in very high percentages. However, a tendency for the males to increase is noticed in the months October, November and December 1956, March 1957 and October 1958 when they formed 43%, 30%, 37%, 33% and 34% respectively.

The same table shows the sex compsoition by percentage from May 1957 to October 1959 in the offshore catch. Excepting

Table 22

Monthly Sex-composition of P.heptadactylus in percentage in the Inshore and Offshore catches

Month	Inshore Catch		Offshore Catch	
	Male (%)	Female (%)	Male (%)	Female (%)
May 1956	15	85	-	-
October	43	57	-	-
November	30	70	-	-
December	37	63	-	-
January 1957	9	100	-	-
February	11	89	-	-
March	33	67	-	-
April	12	88	-	-
May	15	85	17	83
June	29	71	58	42
July	-	-	37	63
August	-	-	30	70
September	13	87	30	70
October	7	93	40	60
November	-	-	56	44
December	6	94	-	-
January 1958	16	84	13	87
February	6	94	45	55
March	28	72	40	60
June	-	-	50	50

contd....

Table 22 (contd...)

Month	Inshore Catch		Offshore Catch	
	Male (%)	Female (%)	Male (%)	Female (%)
July	-	-	24	76
August	-	-	32	68
September	-	-	27	73
October	34	66	37	63
November	7	93	54	46
December	-	-	41	59
January 1959	-	-	38	62
February	-	-	15	85
March	-	-	5	95
April	-	-	19	81
May	-	-	65	35
June	-	-	32	68
July	-	-	4	96
August	-	-	17	83
September	-	-	10	90
October	-	-	7	93

a few months when the males appeared in high percentages, the females were noted to predominate throughout the period of observation. Males surpassed the females in number in June 1957 with 58%, in November 1957 with 56%, in November 1958 with 54% and in May 1959 with 65%. However, in June 1958 the sexes appeared in 1:1 ratio in the offshore catch.

Studies on maturation indicated the possibility of two peak spawning periods, namely, March-June and August-November. In the case of offshore catches, the males either surpassed the females in number or appeared in 1:1 ratio during the months May, June and October. But, in the inshore catch a tendency for the males to increase in number was noticed during the months March and October to December.

Spawning

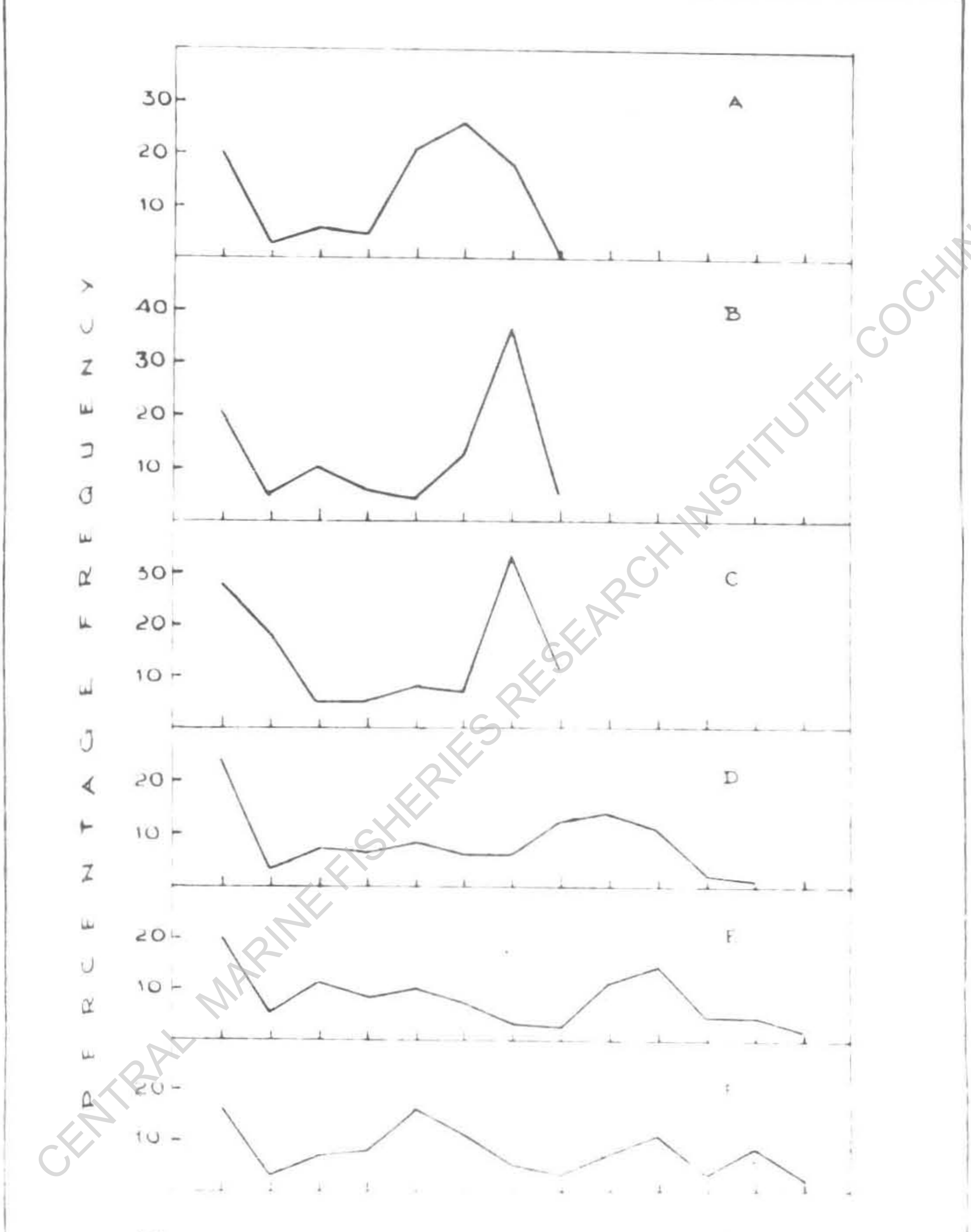
It has been the practice amongst the fishery biology workers to determine the spawning periodicity of a fish based on the ova diameter measurements. It has already been observed earlier that the intra-ovarian eggs undergo a series of changes before becoming mature. In this connection it is worth mentioning the earlier works of Fulton (1899), Clark (1934) and Hickling and Ruthenberg (1936) on the spawning habits of different temperate marine fishes and also of De Jong (1939) on the 13 tropical species of teleostean fishes from the Java Sea.

The attempt made to know the spawning habits of

P. heptadactylus is based on the observations of Hickling and Ruthenberg (1936), "that measurements of the diameters of eggs in ovaries well advanced towards spawning may give evidence of the duration of spawning in a fish of which the spawning habits are unknown. For where the spawning period is short and definite, the batch of transparent yolkless eggs, destined to mature and be spawned will be withdrawn from the general egg-stock in a single group, sharply distinguishable, at least in the later stage of maturation from the stock of small eggs from which it was derived. But when the spawning period is long and indefinite with withdrawal of eggs from the egg-stock, to undergo maturation, will be a continuous process, and there will be no sharp separation between the general egg-stock and maturing eggs. These will pass continuously one into the other".

Ova diameter measurements of 7 ovaries preserved in 10% formalin in the penultimate and mature stages were made use of for this study. Sekharan (1958) found in Rastrelliger canagurta that ova from different regions of the ovary, anterior, middle and posterior, exhibited slight differences in size and appearance. In order to see whether such condition existed in P. heptadactylus, 500 ova diameter measurements were taken separately for different regions in 3 fishes. It was found that no such size difference existed in this fish. Accordingly, from each of the 7 fish 500 ova, irrespective of their position in ovary, were measured for their diameters. A small bit of ovary was teased on a slide and all the intra-ovarian eggs were measured

26. Ova diameter measurements in _P. heptadactylus_.


PERCENTAGE FREQUENCY
A
B
C
D
E
30
20
10
40
0.16
0.32
48

for their diameters excepting those below the size of 0.08 mm which were always innumerable at any stage of maturity in an ovary.

Fig. 26 represents the ova diameter measurements in the advanced stages of maturity for this species. The penultimate stage represented by the fishes 'A', 'B' and 'C' shows two peaks distinguishable from the general egg-stock. Fish 'A' shows a mode at 0.24 mm of immature eggs in stage II with the percentage value of 6 and the other at 0.48 mm of maturing eggs in stage IV with the percentage value of 26. In fish 'B', the eggs in stage II at 0.24 mm are in 10% and those in maturing stage V at 0.56 mm are in 37%. Fish 'C' does not show any mode at 0.24 mm but two modes of maturing eggs at 0.40 mm of stage III and at 0.56 mm of stage V with their percentage values of 8 and 32 respectively. This may be because the fish is a little more advanced in maturity. These observations indicate that when the maturing eggs are ready to spawn, the batch of immature eggs withdrawn from the general egg-stock starts maturing and in its turn gets ready for spawning.

The mature ovaries of fishes 'D', 'E', 'F' and 'G' showed more than two batches of ova. Fish 'D' had 7% of immature ova in stage II at 0.24 mm, 8% of maturing ova of stage III at 0.40 mm and 14% of mature ova at 0.72 mm. Fish 'E' showed 11% ova of stage II at 0.24 mm, 10% of stage III at 0.40 mm when the mature ova at 0.80 mm were only 14%. Fish 'F' did not represent any mode for stage II. The maturing ova in this fish in stage III formed 16% while the mature ova were in two batches at 0.80 mm and 0.96 mm with 11% and 8% respectively. Fish 'G' showed three batches of ova. The maturing ova in stages III and V at 0.40 mm and 0.56 mm formed 6% and 13% respectively and the mature ones at 0.80 mm formed 15%. Thus it is noticed that ripe ova above 0.64 mm in diameter are differentiated into one or two modes indicating thereby that the eggs are shed in batches and the spawning is not a short and restricted one but prolonged. Since the time interval between the shedding of the eggs in two separate batches of eggs and also the number of batches in which all the ripe ova are expelled out are not known, it is difficult to comment on the duration of spawning. But it may be stated here that a mature ovary when opened, is noticed to contain a number of ripe ova dehisced from the ovarian follicles into the lumen and it may be inferred that the duration of spawning may not extend over a much prolonged period since the already dehisced ova may not take much time in getting expelled out.

The two peaks, of immature ova in stage II and the maturing ova in stage III noticed in the penultimate stage, are observed to persist in the mature stage of the ovary also, but the percentage difference in these two groups of eggs is small and they are not sharply distinguishable from one another. Hence, it is likely that the immature eggs may not take more time to develop and join the stock of maturing ones. At the same time, the percentage difference between these eggs and the mature or ripe eggs is also not marked. Thus it is inferred that this crop of eggs develops to maturity to contribute to second spawning, a little later in the course of a few months time.

A number of mature ovaries from which a greater percentage of ripe ova were already shed, showed that the maturing eggs in stage V at 0.56 mm were found to occur to the extent of 20% to 30%. It is unlikely that such a great number of ova will go waste by way of resoption in the ovary. These eggs may be contributing to the second spawning mentioned above.

In the light of these findings, it can be said that P. heptadactylus spawns more than once in a year and that the spawning is prolonged, the liberation of the ripe ova being in successive batches. The periodicity noticed in the spawning appears to pertain to each individual fish. When all the individuals with slight diversity in their spawning periods amongst themselves are considered as a whole, the spawning in this species appears to be a very prolonged one. It is for this reason that all the maturity stages are found throughout the year. But the appearance of these maturity stages and the rings on otoliths and scales in high percentages twice a year and also the findings of two major periods of recruitment in a year, observed in the length frequency studies coinciding with the same periods, prove that the prolonged spawning has two peak periods of March-June and August-November for this species. The fact that there are two peak periods of spawning with the interval roughly of 6 months, appears to indicate spawning twice in a year for each individual.

Karandikar and Palekar (1950) have noticed two spawning seasons (January-April and July-September) in P.tetradactylus. Nayak (1959a) has stated that in P.indicus the main spawning period (April-June) is followed by a supplementary one (October-December). Each of these periods being prolonged, breeding in the species appears to be continuous. Karekar and Bal (1960) have observed that P.indicus breeds throughout the year. It is of interest to note that in Polydactylus opercularis and P. approximans of of eastern tropical Pacific Ocean, Klawe and Alverson (1964) have also observed that the species breed alround the year.

Fecundity

In the population study of any fish species, a knowledge of its reproductive potential obtained by the study on the average count of eggs produced by each female and also the total number of eggs produced by all the females in the population in a year, is of utmost importance. Extensive work carried out in this field by a good number of workers on different species, has yielded information of much value to the fishery science.

Fecundity is known to vary amongst different species and even within the same species depending on the geographical distribution etc. This study helps to establish relationship between variables such as length of fish, weight of fish, weight of gonads, size of the ova etc. Most of the workers have found non-linear relationship between length and fecundity as that between length and weight of the fish, suggesting thereby that fecundity like weight increases in a proportion much greater than the length. Lehman (1953) has found a straight line relationship between fecundity and length in the American shad.

Farran (1938) showed in the Irish herrings that the increase in fecundity was of the order of 4.5 to the power of length. Hickling (1940) observed in the herring of Southern North Sea, the fecundity increasing at a rate above the cube of length. Prabhu (1955) found the fecundity to increase with the length at a rate substantially greater than the fourth power in Trichiurus haumela. Palekar and Bal (1961) noted it in Sillago sihama to increase at a rate of fourth power of its length. An account of fecundity in relation to seasonal variations in spawning periodicity in herring is found in the work of Hickling (loc.cit.) who had compared his observations with those of the earlier workers and stated, "least fecund in spring spawners, more fecund in winter spawners, still more fecund in autumn spawners and most fecund in summer spawners".

MacGregor (1957) had carried out a detailed study on the fecundity of Pacific sardine (Sardinops caerulea) with different variables and found that fecundity-weight gave a better correlation than either fecundity-length or fecundity-age. Bagenal (1957) in his work on the fecundity with the variables length and weight of the fish and weight of the gonads in the long rough dab (Hippoglossoides plastessoides) considers that length is an easier variable to handle than the other two, when large samples are to be examined in fecundity studies.

Karekar and Bal (loc.cit.) and Nayak (loc.cit.) have studied the fecundity in Polydactylus indicus and there is no other account on the fecundity of Polynemids in the published literature.

For this study, 38 P.heptadactylus ranging in sizes from 136 mm to 210 mm in the penultimate stage of maturity, were made use of. In each, the weight of the preserved ovaries (a pair) was recorded; a portion of the ovary was taken and weighed separately and all yolky ova contained in the latter were counted, from which the total number of ova in the pair of ovaries as a whole was computed. The ova diameter studies have indicated that the ripe ova in this species are shed in batches. Since the number of batches in which they are shed in a year and the time interval between each of them are not known, it is difficult to estimate the correct number of ova destined to be spawned in a year by this method. However, it has not been possible to devise any other suitable alternative means of estimating fecundity in P. heptadactylus. Fairbridge (1951) in his work on Neoplatycephalus macrodon and Karekar and Bal (loc.cit.) in P.indicus have noticed similar instances in the fecundity studies of the respective species.

27. Fecundity in relation to fish-length in
P. heptadactylus

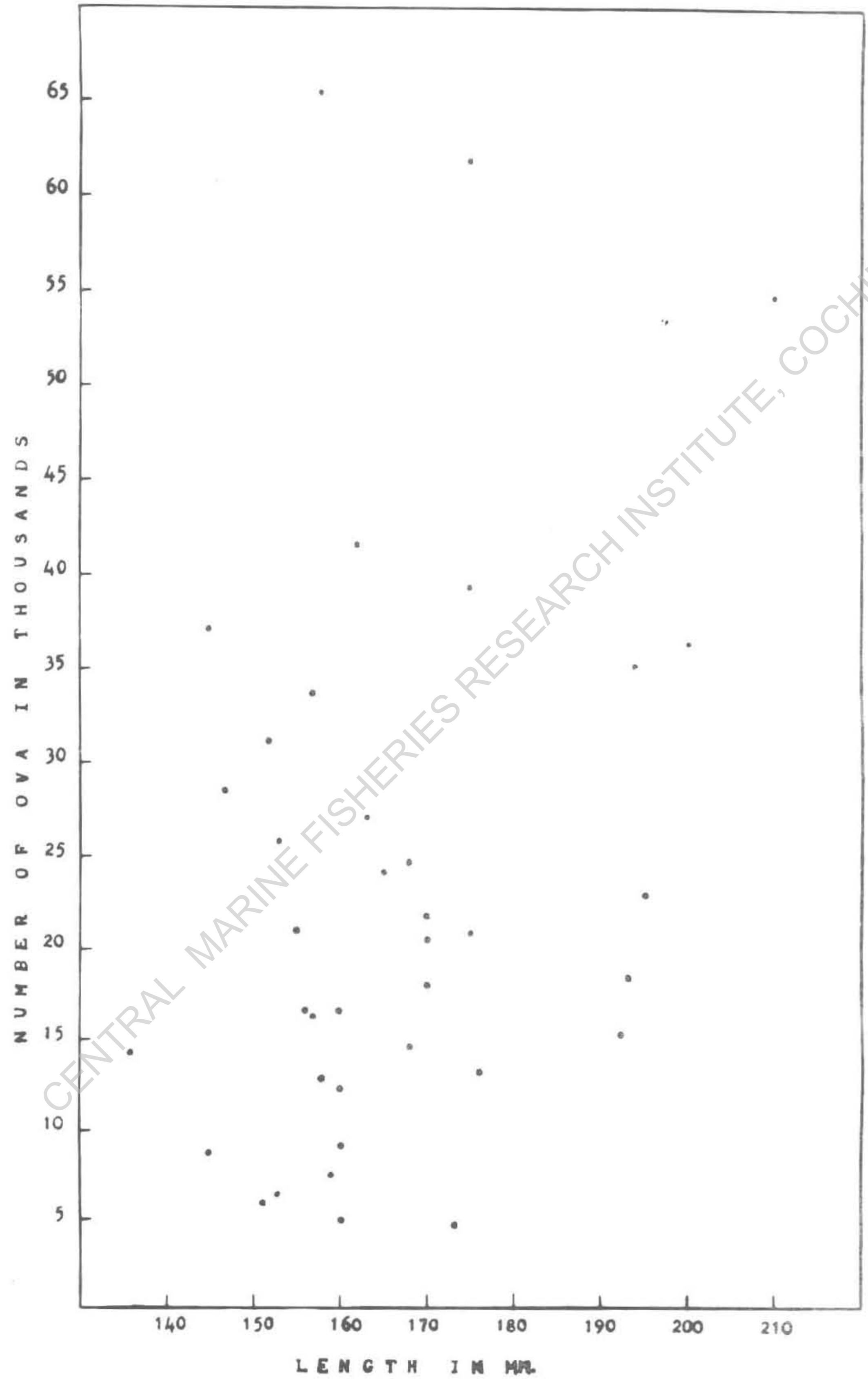

65
60
55
50
45
40
35
30
25
20
15
10
5
NUMBER OF OVA IN THOUSANDS
140
150
160
170
180
190
200
210
LENGTH IN MM.

Table 23

Data showing body length and weight of gonad in relation to fecundity in P. heptadactylus

Furcal length	Weight of the ovary (gm.)	Weight of a small piece of ovary	Number of ova in the small piece of ovary	Number of ova in 1 gm. of ovary	Number of ova in whole of the ovary
210	6.312	0.094	816	8,681	54,794
200	2.595	0.036	505	14,028	36,403
195	1.739	0.059	782	13,254	23,049
194	2.011	0.037	649	17,540	35,273
193	2.701	0.079	541	6,848	18,496
192	1.809	0.040	342	8,550	15,467
176	1.396	0.059	560	9,492	13,251
175	3.219	0.070	1,347	19,243	61,943
175	3.081	0.056	715	12,768	39,338
175	2.261	0.040	370	9,250	20,914
173	0.445	0.117	1,193	10,197	4,538
170	0.983	0.047	982	20,894	20,539
170	2.015	0.060	652	10,867	21,897
170	1.875	0.056	539	9,625	18,047
168	1.355	0.040	436	10,900	14,770
168	1.969	0.078	980	12,564	24,739
165	1.904	0.071	903	12,718	24,215
163	4.206	0.104	673	6,471	27,217
162	2.452	0.086	1,461	16,988	41,655

contd....

Table 23 (contd..)

Furcal length	Weight of the ovary (gm.)	Weight of a small piece of ovary	Number of ova in the small piece of ovary	Number of ova in 1 gm. of ovary	Number of ova in whole of the ovary
160	0.966	0.053	682	12,868	12,430
160	0.651	0.029	410	14,138	9,204
160	0.413	0.026	313	12,038	4,972
160	2.526	0.051	337	6,608	16,692
159	0.827	0.035	315	9,000	7,443
158	1.329	0.074	720	9,730	12,931
158	3.281	0.083	1,655	19,940	65,423
157	1.581	0.049	510	10,408	16,455
157	2.311	0.134	1,950	14,552	33,630
156	1.599	0.031	324	10,452	16,713
155	1.573	0.050	670	13,400	21,078
153	1.016	0.067	422	6,299	6,400
153	1.651	0.033	516	15,636	25,815
152	2.189	0.070	989	14,129	30,928
151	0.729	0.032	255	7,969	5,809
147	2.293	0.052	648	12,462	28,575
145	1.975	0.064	1,202	18,781	37,092
145	0.704	0.031	390	12,581	8,857
136	1.100	0.036	472	13,111	14,422

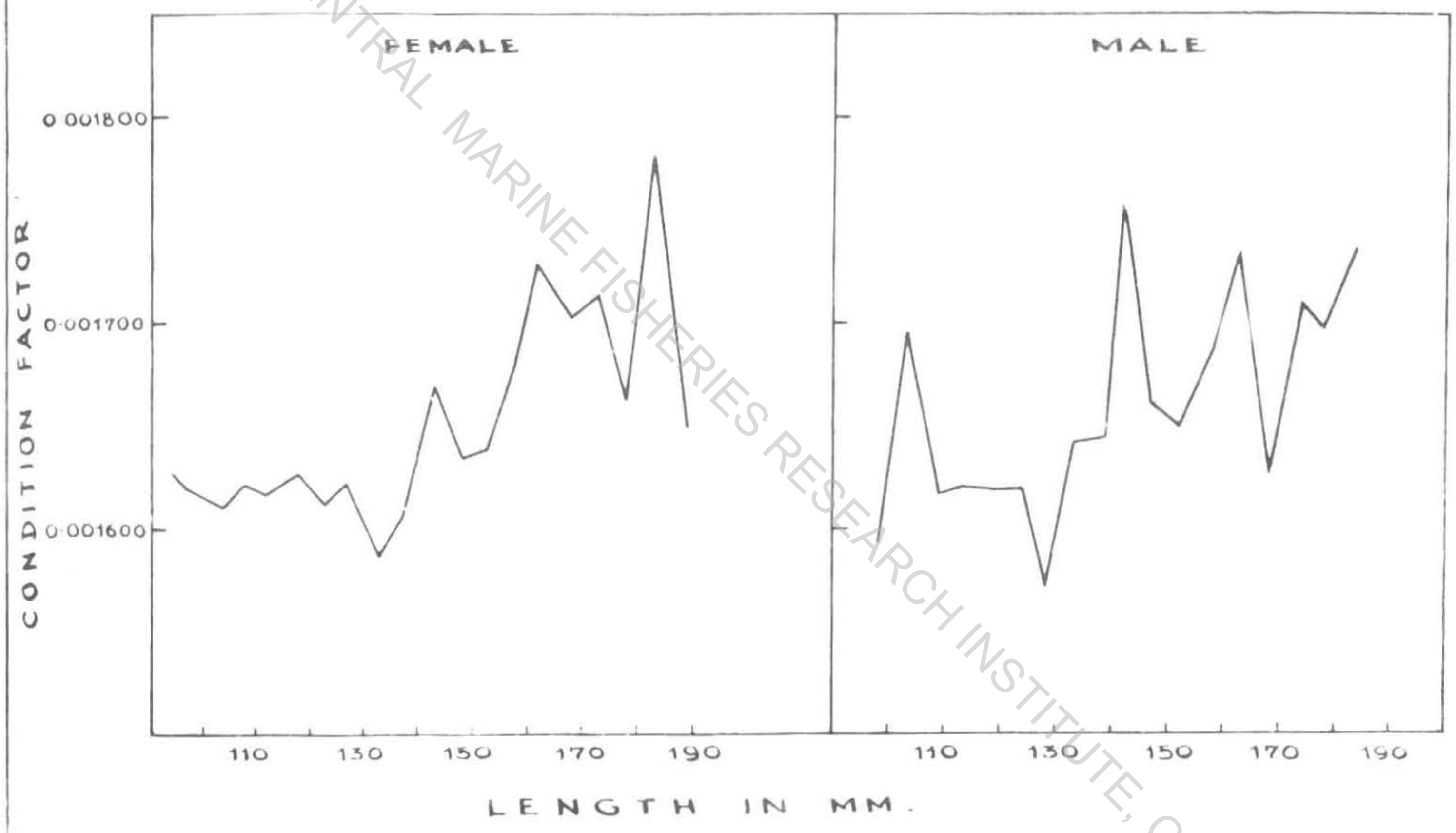
Fig. 27 shows that the number of ova destined to be spawned varied widely in fish of the same length. The highest number of 65,423 ova was estimated at a fish length of 150 mm. It will be interesting to note that another fish of the same length showed a fecundity value of 12,931 ova which was roughly 1/5 of the earlier value. Such discrepancies in the estimated number of ova in varied proportions at different lengths of 145 mm, 153 mm, 157 mm, 160 mm, 170 mm and 175 mm as noticed in Table 23, seem to clearly indicate that the ova in this species are shed in several batches.

Ponderal Index or Condition Factor

Very often variation is noticed from the expected weight for the length of a particular fish or groups of individuals. This variation is due to biological and physiological factors such as sex, age, fatness, maturation and spawning. This general 'well being' is commonly referred as the 'condition'. It helps in knowing the interseasonal changes due to nutrition and reproduction of the fish and Hecht (1916) has correctly described these changes as "corresponding to cyclic physiological changes that the species undergo in the matter of nutrition and reproduction".

The ponderal index or the condition factor can be measured and is calculated from the formula:-

28. Condition factor in male and female *P. heptadactylus* in relation to fish-length.

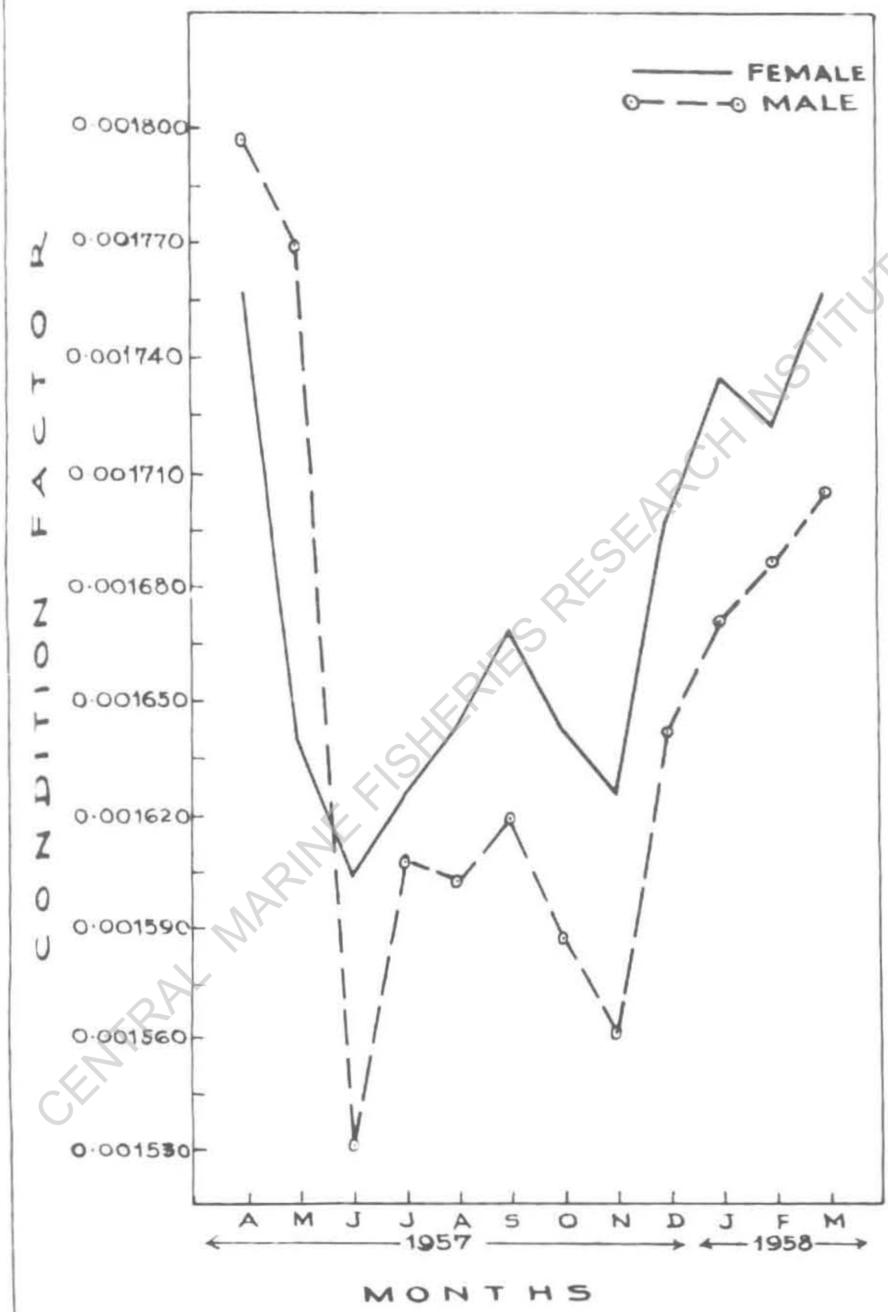

FEMALE
MALE
CONDITION FACTOR
0.001800
0.001700
0.001600
110
130
150
170
190
LENGTH IN MM.

$$K = \frac{100\,W}{L^3} \quad \ldots\ldots \quad \text{where } W = \text{weight}, \; L = \text{Length} \text{ and } K = \text{condition factor.}$$

The condition factor for 419 females ranging in size from 78 mm to 245 mm and 181 males ranging from 80 mm to 210 mm was calculated separately. Fig. 28 shows the condition factor in females and males for lengths at 5 mm class-interval. The condition is observed to increase with the length. In the case of female P.heptadactylus the condition is found to fall first at the length 133 mm and in males at 128 mm. According to Hart (1946) this fall in the condition is due to the onset of maturity and he states, "The point of inflexion, on a curve showing this diminuation of 'K' with increasing length is thus a good approximate indication of the length at which sexual maturity is attained." Thus the condition falling at 133 mm in female P.heptadactylus and in males slightly at a smaller length at 128 mm, may be attributed to the onset of first maturity in them. The result obtained earlier by the maturity curve for females supports this observation. The fluctuations noticed thereafter in the condition at different lengths in both the sexes are due to the cyclic spawning, recovering and maturing of the gonads.

The monthly average condition factors from April 1957 to March 1958 are plotted separately for females and males in Fig. 29. It is seen that in females the condition with a high value of 0.001757 in April falls down to 0.001604 in June. After

29. Monthly average condition factor for male and female *P. hexadactylus* from April 1957 to March 1958.



FEMALE
MALE
0·001800
0·001770
0·001740
0·001710
0·001680
0·001650
0·001620
0·001590
0·001560
0·001530
CONDITION FACTOR
A M J J A S O N D J F M
1957
1958
MONTHS

this, a steady gain in the condition to the value of 0.001668 in the month of September is noticed. The condition drops again to the value of 0.001626 in November and then begins to increase steadily to the value of 0.001764 in March. The pattern in which the condition varies during different months in the case of males is the same as that for the females. The falling of the condition from 0.001797 in April till June to the value of 0.001531, the gaining from this to 0.001619 in September, the fall again to 0.001562 in November followed by a rise to 0.001705 in March is parallel to that found in females.

From the study on maturity and spawning of this species it is noted that there are two peak spawning periods in a year. The condition starts falling in both the sexes during spawning and thereafter it begins to increase suggesting the recovery of the gonads.

LENGTH-WEIGHT RELATIONSHIP

One important aspect of growth in a fish is the relationship between length and weight of its body. The mathematical relationship between these two comes to aid in the analysis of catch statistics. The relation thus established between them helps in converting one factor into the other. The length of a fish can be measured more quickly and accurately than the weight and in the biological studies length is a measure more commonly used in the growth studies in relation to scales, otoliths etc. For the back calculations of the past growth also it is necessary to know the length-weight relationship. Further this relationship helps in measuring the variation from the expected weight for a particular fish as a result of physiological factors, to which the term 'condition' is applied.

It has been found that many fish species obey the cube law wherein the weight increases as the cube of the length, however, some fishes are noticed to deviate from this law. The length-weight relationship is generally expressed by the formula:-

$W = aL^b$ where W = weight of the fish

L = length of the fish

a = constant

and b = exponent.

LeCren (1951) states that according to Hile (1936) and Martin (1949) the value of the exponent 'b' usually lies between 2.5 and 4.0. Allen (1938) observes that for an ideal fish maintaining the same shape, the exponent 'b' equals 3. It has also been found that the value of 'b' differs for a fish from different localities and of different sexes or ages.

In order to see whether the value of the exponent 'b' in *P. heptadactylus* differs for males and females, the analysis has been carried out separately for each. In all 181 males ranging from 80 mm to 210 mm and 419 females ranging from 78 mm to 245 mm in furcal lengths were weighed in grams. The males were grouped into 9 size-groups and females into 12with 15 mm class intervals.

If these average weights are plotted against the average lengths, a curve will be obtained. The formula $W = aL^b$ which represents the curve can be rewritten as $\log W = \log a + b \log L$ representing a straight line. Hence, to convert the curve into a straight line graph, the logarithmic values were taken for both lengths and weights. Tables 24 and 25 show the logarithmic values of lengths and weights with squares of log lengths and products of log lengths and log weights for males and females respectively. The values of 'a' and 'b' in the above formulae were obtained by using the equations:

$$b = \frac{\varepsilon xy - \frac{(\varepsilon x)\quad(\varepsilon y)}{n}}{\varepsilon x^2 - \frac{(\varepsilon x)^2}{n}}$$

Table 24

Length-weight relationship for male *P. heptadactylus*.

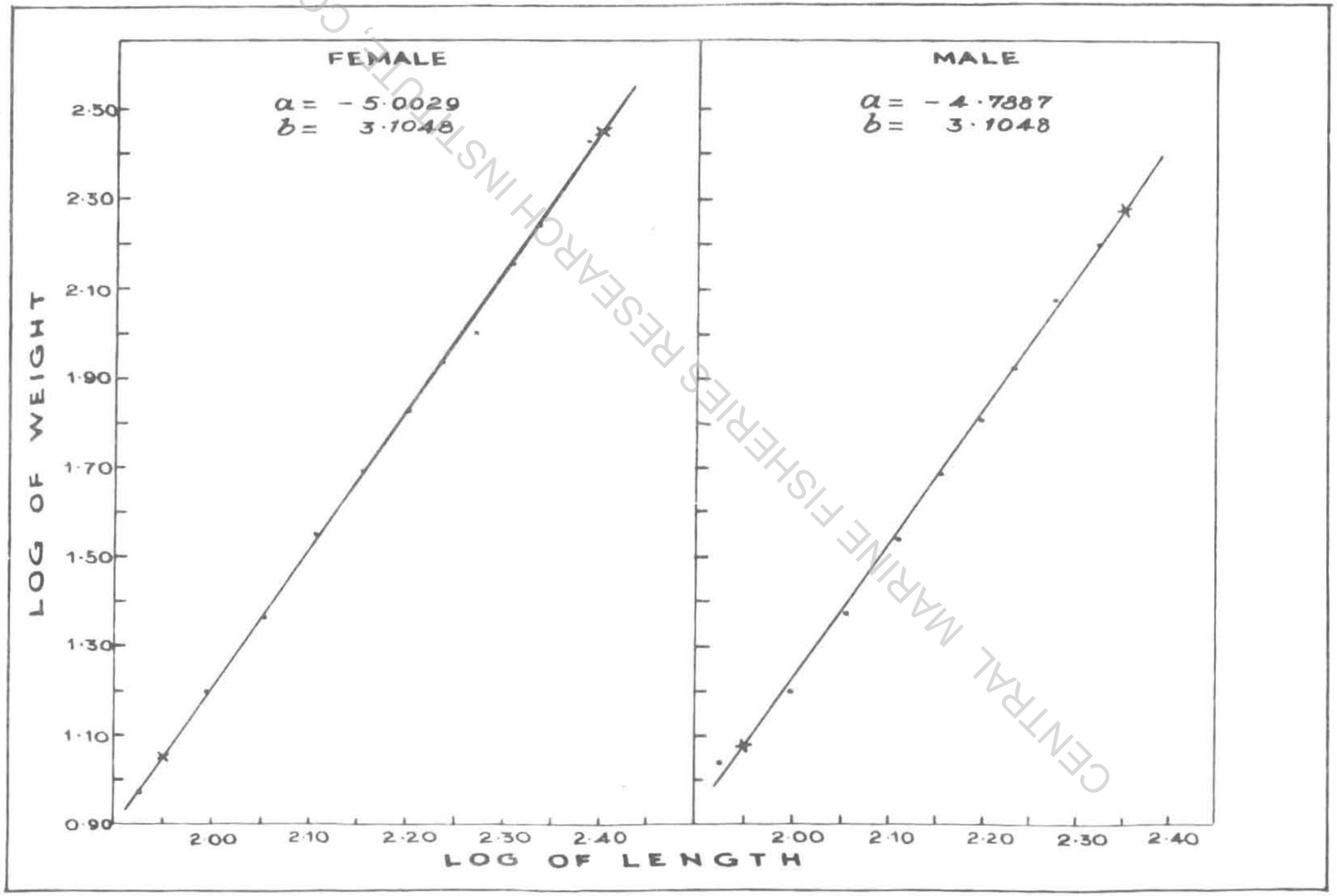
Size-group (Mid-point mm.)	No. of specimens	Average furcal length in mm. (L)	Average weight in gm. (W)	Log. L X	Log. W y	x^2	xy	Calculated weight in gms.
83	3	84.00	10.83	1.9243	1.0346	3.7029	1.9908	9.60
98	11	99.36	15.81	1.9972	1.1990	3.9888	2.3946	15.82
113	24	113.20	23.65	2.0539	1.3738	4.2185	2.8216	24.29
128	47	128.87	34.51	2.1099	1.5379	4.4516	3.2448	35.33
143	40	142.82	48.48	2.1548	1.6855	4.6431	3.6319	49.28
158	36	157.47	65.24	2.1970	1.8145	4.8268	3.9864	66.56
173	12	171.25	83.54	2.2335	1.9219	4.9885	4.2925	87.38
188	5	188.00	118.60	2.2742	2.0741	5.1719	4.7169	112.30
203	3	210.00	158.00	2.3222	2.1987	5.3926	5.1058	141.40
n=9	Σ 181	---	---	Σ 19.2670	Σ 14.8400	Σ 41.3857	Σ 32.1853	

Table 25

Length-weight relationship for female *P. heptadactylus*

Size-group (Mid-point mm.)	No. of specimens	Average furcal length in mm (L)	Average weight in gms (W)	Log. L X	Log W y	x^2	xy	Calculated weight in gms
83	10	84.40	9.47	1.9263	0.9763	3.7106	1.8806	9.80
98	25	98.92	15.75	1.9953	1.1973	3.9812	2.3889	15.11
113	37	113.20	23.26	2.0539	1.3666	4.2185	2.8068	23.53
128	63	128.07	35.69	2.1072	1.5525	4.4403	3.2714	34.63
143	64	143.13	49.26	2.1556	1.6925	4.6466	3.6483	48.75
158	65	158.84	67.31	2.2009	1.8281	4.8439	4.0234	66.62
173	47	171.93	86.13	2.2353	1.9352	4.9965	4.3257	88.22
188	49	187.67	111.94	2.2732	2.0488	5.1674	4.6573	114.30
203	30	203.93	143.40	2.3094	2.1565	5.3333	4.9802	145.00
218	19	217.21	174.73	2.3369	2.2423	5.4611	5.2400	181.00
233	6	234.33	227.33	2.3698	2.3566	5.6159	5.5846	222.50
248	4	244.75	269.62	2.3886	2.4308	5.7054	5.8062	270.10
n = 12	Σ 419	--	--	Σ 26.3524	Σ 21.7835	Σ 58.1207	Σ 48.6134	[illegible]

20. Length-weight regression of female and male *P. pentadactylus*.


FEMALE
a = -5.0029
b = 3.1048
MALE
a = -4.7887
b = 3.1048
LOG OF WEIGHT
0.90
1.10
1.30
1.50
1.70
1.90
2.10
2.30
2.50
LOG OF LENGTH
2.00
2.10
2.20
2.30
2.40

and

$$a = \bar{y} - b\bar{x} \qquad \text{where} \quad x = \text{log of length}$$

y = log of weight

n = number of groups

$$\bar{y} = \frac{\varepsilon y}{n}$$

and $$\bar{x} = \frac{\varepsilon x}{n}$$

The values of 'b' thus obtained for the males and females are 3.0072 and 3.1048 respectively. The constant 'a' for male is 0.00001627 and for females 0.000009933. Thus the relationship for the males can be written as -

$$W = 0.00001627\ L^{3.0072} \qquad \text{and}$$

for females as

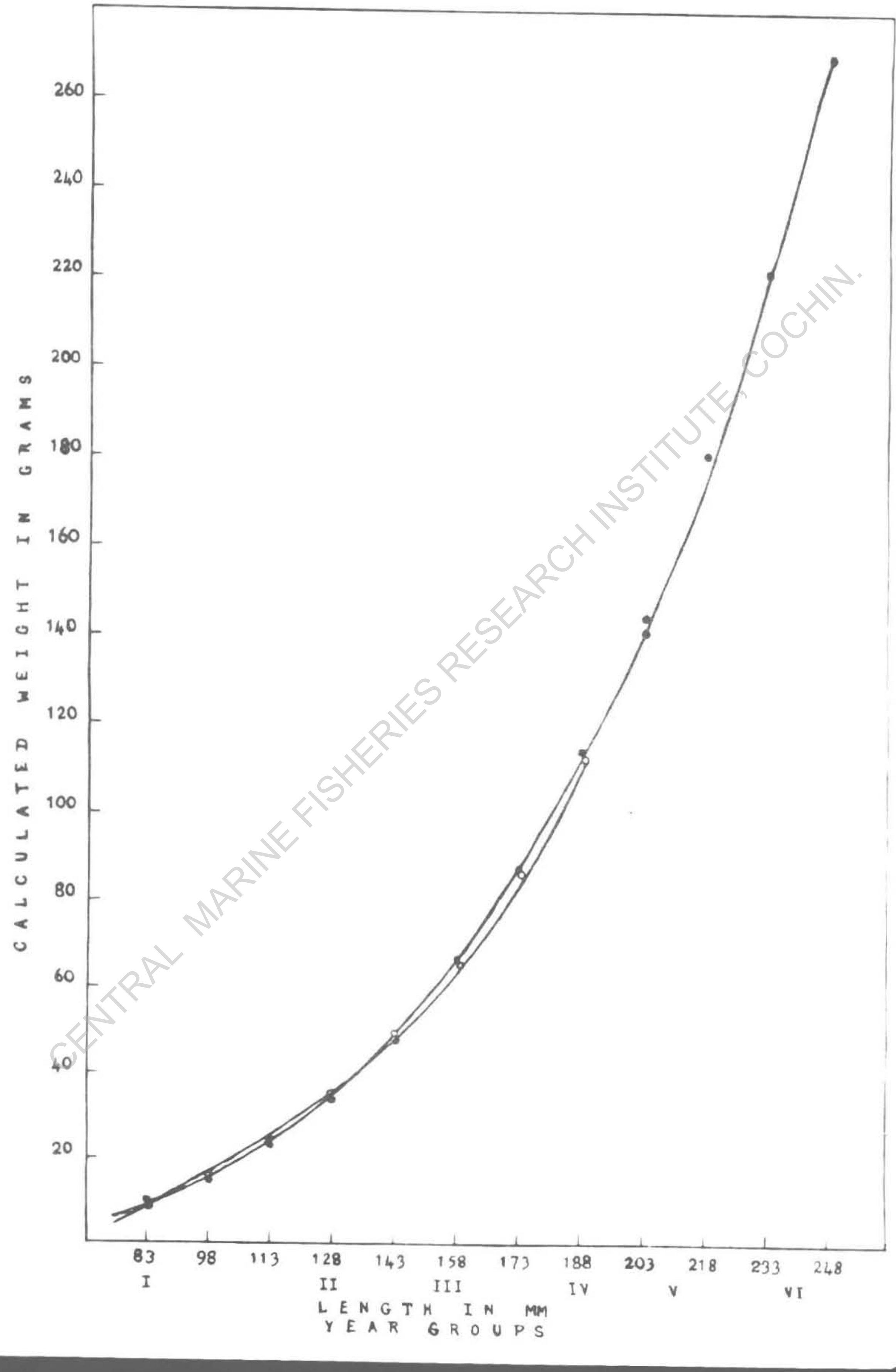
$$W = 0.000009933\ L^{3.1048}$$

This shows that the relation obeys the cube law in both the sexes. The proportion in which the weight increases with length, appears to be slightly greater in females than in males.

Fig. 30 shows the logarithmic values of the observed lengths poltted against the logarithmic values of the observed weights, for males and females separately. It can be seen that a straight line can be fitted in closely in each case by the method of least squares (Snedecor, 1940).

Fig. 31 shows the growth curves for males and females wherein the calculated weights were plotted against lengths at 15 mm

31. Length-weight curve for male and female *P. heptadactylus*.


CALCULATED WEIGHT IN GRAMS
260
240
220
200
180
160
140
120
100
80
60
40
20
83
98
113
128
143
158
173
188
203
218
233
248
I
II
III
IV
V
VI
LENGTH IN MM
YEAR GROUPS

class intervals by using the above growth formula, viz. $W = aL^b$ i.e. -

$$W = 0.00001627\ L^{3.0072} \quad \text{or}$$

$$\log W = -4.7887 + 3.0072 \log L \text{ for males; and}$$

$$W = 0.000009933\ L^{3.1048} \quad \text{or}$$

$$\log W = -5.0029 + 3.1048 \log L \text{ for females.}$$

It is observed from the figure that the increase in weight for males at different lengths is fairly in agreement with that for females, the differences between them ranging from 0.2 gm in the smallest length of 83 mm to 3.5 gms in the largest length of 203 mm. No males were observed in the samples beyond this size-group. Excepting at lengths 98 mm, 113 mm, 128 mm and 143 mm the females showed slightly higher weights than the males. The difference in weights of males and females at different lengths is so small and negligible that it cannot be considered significant in the catch statistics. This slight difference may be due to the personal error in weighing or due to the grouping of individuals with slight variations in weights caused by their 'condition' factor.

The largest male examined was measuring 210 mm in furcal length and the largest female 273 mm, the corresponding weights of them being 157 gms and 364 gms respectively. Apart from the minor variations noticed in the weights for males and females at different lengths, it can be generalised that when

Table 26

Increase in weight in the successive eight years in *P. heptadactylus*

Age	Length (mm)	Calculated weight (gms.)	Increase in weight in the successive years
1	83	10	10
2	128	36	26
3	158	67	31
4	188	113	46
5	213	168	55
6	237	234	66
7	255	294	60
8	273	364	70

P. *heptadactylus* is one year old (Table 26) reaching 83 mm in length, it weighs about 10 gms; when two years at 128 mm, weighs 36 gms; when three years at 158 mm, weighs 67 gms; when four years at 188 mm, weighs 113 gms; when five years at 213 mm, weighs 168 gms; when six years at 237 mm, weighs 234 gms; when seven years at 255 mm, weighs 294 gms and when eight years at 273 mm, weighs 364 gms. The increase in weights in the successive eight years of life for this fish is observed to be 10 gms, 26 gms, 31 gms, 46 gms, 55 gms, 66 gms, 60 gms and 70 gms in the same order. Thus the annual increase in weight in the successive age groups appears to be almost regular excepting in the seventh and eighth years when the annual increase remains more or less constant.

The bulk of the trawl catch for this species consisted of the third and fourth year classes. The fish is found to attain maturity after the completion of two years. The fish in the third year may have completed the first spawning or even the second. To have a sustaining yield in the fishery and also from the point of view of preference for heavier fish by the consumer, it will be beneficial to catch the fish in the fourth year of its life and above.

HERMAPHRODITISM

Apart from the occasional or teratological hermaphroditism, normal hermaphroditism and sex reversal are often met with in some of the teleosts, Teratological hermaphroditism is found amongst herrings, cods, mackerals, sardines and some of the Pleuronectidae whereas eels, symbranchids and some species belonging to the three families of percoids, viz., Maenidae, Sparidae and Serranidae are normally hermaphroditic and some exhibit sex reversal.

The ovotestis in Sparids is divided into distinct male and female parts. Here the gonad is gonochoritic and only one of the sexes functions at a time, being either protandric or proterogynous. Self fertilization is not possible.

D'Ancona (1945) has referred to protandry in *Sparus auralies* wherein the male germ cells mature earlier than those of female. In other Sparids viz., *Diplodus* spp., he has observed testicular and ovarian parts in the same gonad but only one of them reaching maturity. This condition presents a transition from hermaphroditism and is considered primitive to gonochorism.

Serranids are synchronously hermaphroditic wherein, as in Sparids, the male and female parts are very distinct in a gonad, but unlike in them, both the sex elements, sperms and ova develop and become active simultaneously. If there are no physiological and genetic barriers, self-fertilization seems to be possible. It is interesting to note that Clark (1959) has reported functional hermaphroditism and self-fertilization in a Serranid fish, *Serranellus subligarius*. Smith (1959) has found *Hypoplectrus unicolor*, *Prionodes phoebe*, *P. tabacarius* and *P. tigrinus* to be synchronous hermaphrodites among members of the subfamily Seraninae from Bermuda. Mead (1960) has found ovotestes similar in general structure to those of the monoecious percoids in ten species of the order Iniomi.

Another form of functional hermaphroditism is sex reversal. Essenberg (1926) has studied the sex reversal in *Xiphophorus helleri*, Liu (1944) in *Monopterus javanensis*, Zei (1949) in *Maena smaris*, *M. chryselis* and *Pagellus erythrinus*, Lavenda (1949) in *Centropristes striatus* and Smith (loc.cit.) in *Epinephelus guttatus*, *E. striatus*, *Mycteroperca bonaci*, *M. tigris*, *M. fulcata*, *M. venenosa*, *Cephalopholis fulvus*, *Petrometopon cruentatus*, *Alphestes afer* and *Promicrops itaiara*. Liu and Ku (1951)* have described in detail the histological changes taking place in the gonad of *Monopterus* during sex transformation. In all the species cited where there is sex reversal they are proterogynous, the females appearing in smaller ones at a younger age and males in larger ones at an older age. The individuals first behave as females and later on as males with a phase of intersex in between. Size dimorphism between the sexes in a dioecious species may as well hint the possibility of hermaphroditism in these species.

In India, excepting a few cases of teratological

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* Histological changes in the gonad of *Monopterus* during sex transformation, *Sinensia* 2 : 85-109.

hermaphroditism reported by Chacko and Krishnamurthy (1949) in Hilsa ilisha, Sathyanesan and Rajan (1953) in Cirrhina reba, Sathyanesan (1957) in Barbus stigma, Prabhu and Raja (1959) in Rastrelliger canagurta and Raja (1963) in Sardinella longiceps, no work on the hermaphroditism in Indian fishes is available. The present study deals in detail with the hermaphroditism in Polynemus heptadactylus mentioned earlier by Nayak (1959b).

Material and Methods

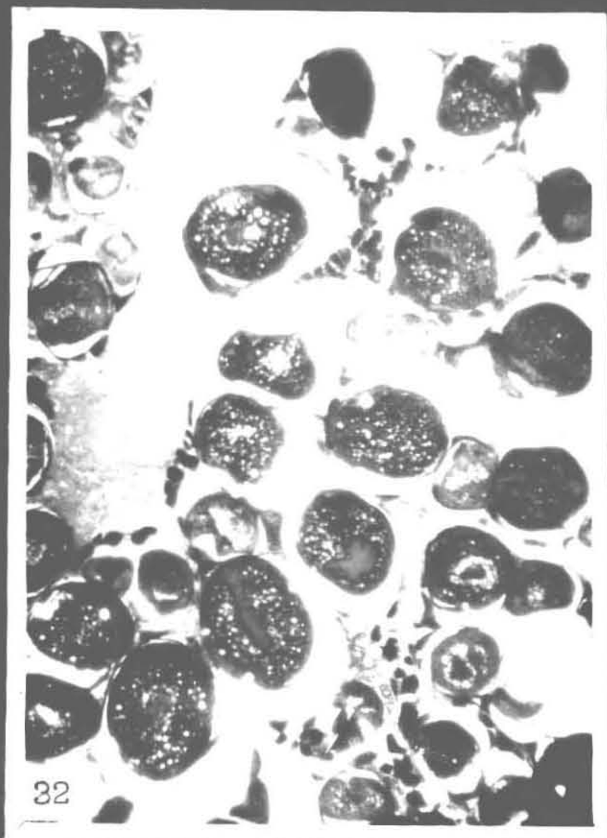
Of the 858 P.heptadactylus examined during the period from October 1958 to October 1959, 148 were hermaphrodites. Maturity scales adopted for normal female were used here, as the nature and also the diameter of the ova in different maturity stages were found identical. Further these stages were confirmed by microsections stained with delafield's haematoxylin and eosin.

Ovotestes

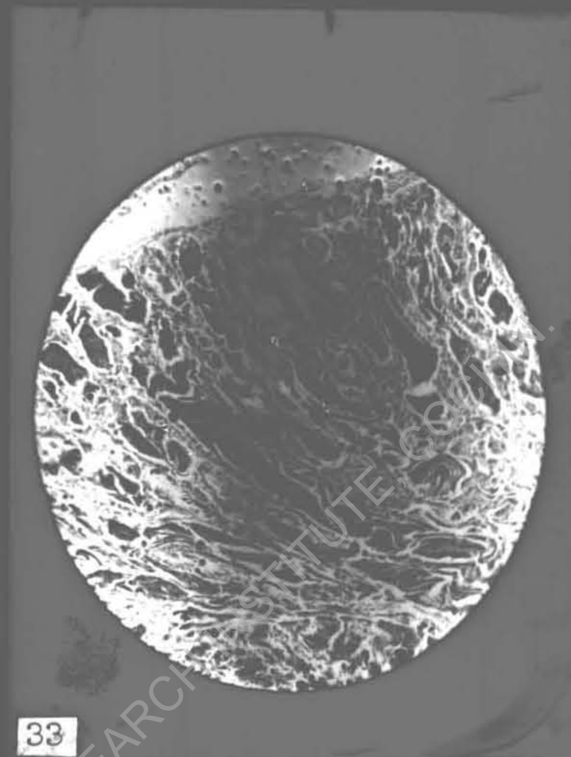
P. heptadactylus is normally dioecious where sexes are separate, but sometimes monoecious, with individual members possessing each, a pair of ovotestes. There are no external characters by which hermaphrodites could be distinguished from the unisexual individuals.

The paired elongated ovotestes suspended by the mesenteries, lie side by side with the air bladder above the intestine below. Anteriorly, they extend upto the anterior end of the cardiac stomach and posteriorly into the coelom

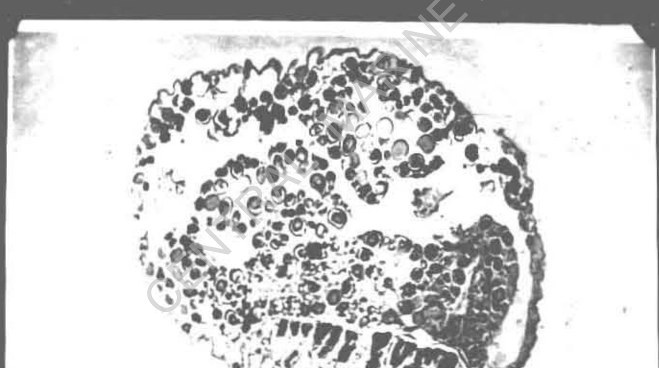
32.	T.S. of ovary in unisexual female, *P. heptadactylus*	x 50
33.	T.S. of testis in unisexual male	x 36
34.	T.S. of ovotestis in immature hermaphrodite individual	x 45
35.	T.S. of ovotestis in immature hermaphrodite individual	x 120



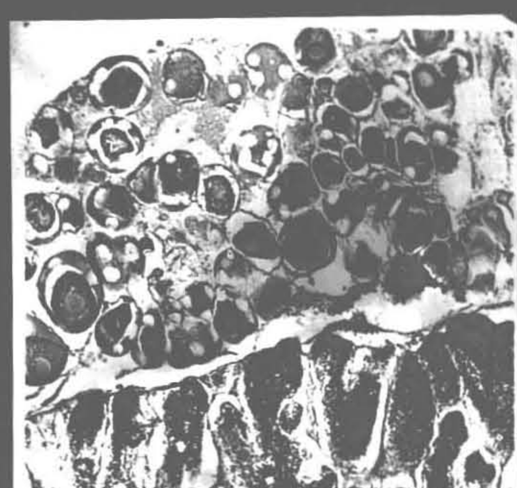
32



33



34



35

beyond the anal opening. The two ovotestes may be of the same length or the left one slightly longer than the right. The testicular parts of both the ovotestes face each other on the inner side and run from end to end. The extent of development of the testicular part may vary from fish to fish, but it is the ovarian part that always occupies comparatively a larger portion. In an immature ovotestis preserved in 10% formalin, the testicular portion can easily be separated from the ovarian portion.

The cross section of the normal ovary (Fig. 32) shows an outer fibrous connective tissue layer. The oocytes in their various developmental stages are seen in the ovigerous lamellae. The testis (Fig. 33) in an unisexual individual is also covered by a fibrous layer and is seen filled up with a number of seminiferous tubules in which the male elements at various stages of spermatogenesis are seen. When fully mature, sperms with long tails are seen to aggregate together and form a number of bundles.

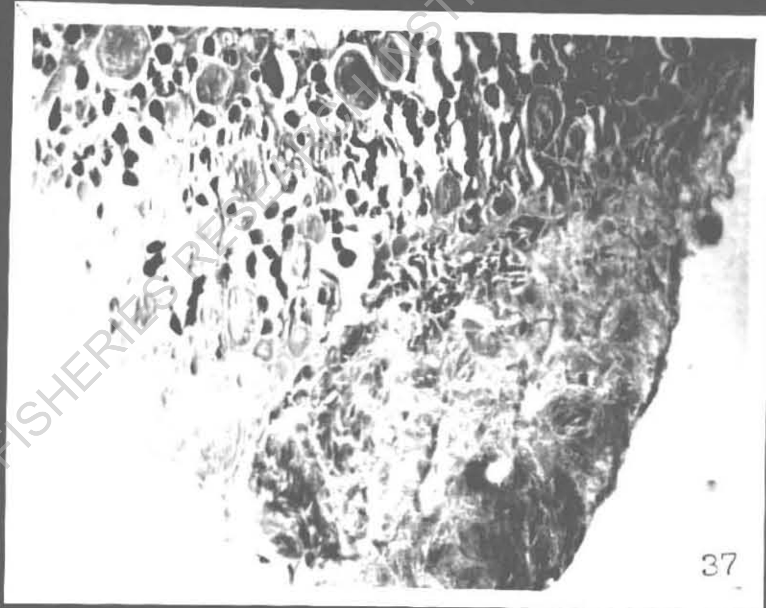
An ovotestis has a common fibrous layer surrounding both male and female parts. An immature ovotestis (Figs. 34 & 35) shows a slender septum separating the testicular and ovarian parts. The ovarian part has its ovarian lamellae all around containing the developing oocytes. In the testicular part, on the other hand, the development of the male sexual elements appears to begin first in the region of the septum, separating

36. T.S. of ovotestis in maturing hermaphrodite individual of _P. heptadactylus_ x 40

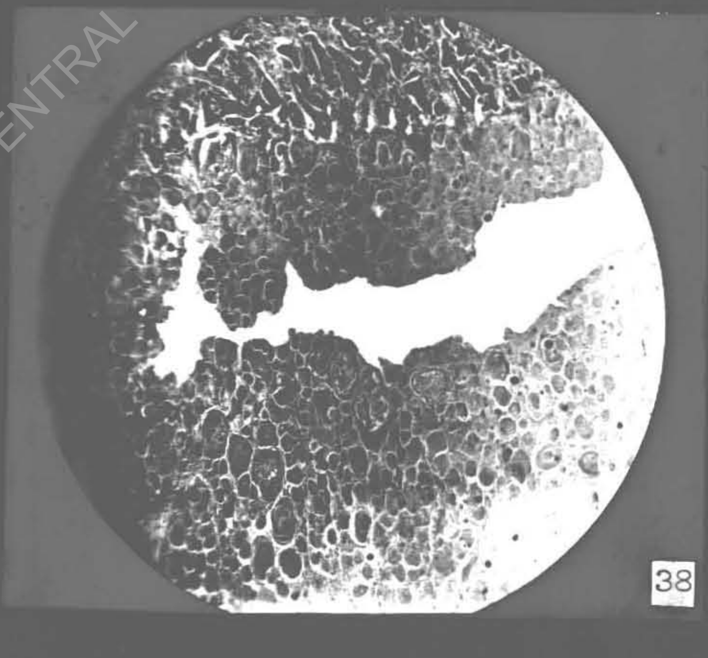
37. T.S. of ovotestis of spent hermaphrodite individual x 40

38. T.S. of ovotestis of spent recovering hermaphrodite individual x 36

36



37



38

it from the ovarian part and then gradually progresses towards the opposite periphery.

In a maturing ovotestis (Fig. 36) the ovarian lamellae completely fill the lumen in the centre. Most of the ova are large and filled with yolk. In the testicular part the development of the seminiferous tubules is complete and thus attains the form of a normal testis. The seminiferous tubules are all full with male sexual elements in their developmental stages.

The spent hermaphrodite (Fig. 37) has a number of small immature ova along with a few large degenerating and resorbing residual ova in the ovarian part. The testicular part at this stage does not have the dense and compact appearance of the maturing stage, but on the other hand, it is thin with loosely scattered developmental stages of the male sexual elements. This may be due to the shedding of the sperms along with the ova.

Finally, in the recovering hermaphrodite (Fig. 38) the ovarian part with a few residual ova is seen to develop once again and the testicular part in contrast to the earlier spent conditions, is observed to contain some sperm bundles.

Hermaphrodites and Unisexual individuals of *P. heptadactylus* in the samples

During the 13 months of observation it was noticed

Table 27

Monthly percentage of Hermaphrodite individuals of *P. heptadactylus* in the catch

Month	No. of fish examined	Hermaphrodite	
		No.	%
October 1958	163	3	2
November	131	25	19
December	65	4	6
January 1959	50	8	16
February	55	9	16
March	52	15	29
April	53	10	19
May	51	17	33
June	49	11	22
July	26	2	8
August	52	5	10
September	62	14	23
October	49	22	45

Table 28

Monthly percentage distribution of different stages of maturity in Hermaphrodite individuals of *P. heptadactylus*.

Months	Maturity Stages						
	I	II	III	IV	V	VI	VII
October 1958	-	67	33	-	-	-	-
November	12	64	-	-	4	4	16
December	-	75	-	-	-	-	25
January 1959	13	62	-	12	-	-	13
February	33	34	-	11	11	-	11
March	-	13	-	-	-	-	87
April	-	20	-	20	-	-	60
May	-	23	-	12	-	-	65
June	-	82	-	-	-	-	18
July	-	-	-	-	-	-	100
August	-	80	-	-	-	-	20
September	-	-	-	43	-	-	57
October	4	50	-	-	5	-	41

that hermaphrodites formed nearly 17% of *P. heptadactylus* in the samples. Table 27 on the monthly percentage of hermaphrodites occurring in the samples shows that the percentages varied from 2 to 45, the lowest of 2% being in October 1958 and the highest of 45% in October 1959. Except during the three months of October and December 1958 and also July 1959, their percentages were always above 10.

It can be seen from the Table 28 that the hermaphrodites in maturity stage I appeared in the months of November 1958 and January, February and October 1959. Stage II occurred almost all the months in very high percentages ranging between 13 in March 1959 and 82 in June 1959. The maturing stage III was recorded only once in October 1958. Stage IV appeared in January, February, April, May and September 1959. It formed the lowest percentage of 11 in February and the highest of 43 in September 1959. Stage V was almost rare and appeared only thrice during November 1958, February and October 1959. Only one individual in stage VI was noticed in November 1958. The spent hermaphrodites were noted as in the case of unisexual females during all the months in varying percentages.

As regards the maturity stages in the various length groups, it is seen from the Table 29 that immature individuals alone appeared upto the size of 113 mm. In the next size of 128 mm, individuals in the maturing stage V and spent ones in stage VII were seen to form 7% each. After this the percentage of spent

Table 29

Percentage of Hermaphrodite individuals of *P. heptadactylus* in different stages of maturity at each 15 mm length.

Size-group (Mid-point mm.)	Maturity Stages I	II	III	IV	V	VI	VII
98	67	33	-	-	-	-	-
113	17	83	-	-	-	-	-
128	36	50	-	-	7	-	7
143	-	76	-	-	3	-	21
158	-	35	3	8	-	3	51
173	-	28	-	16	-	-	56
188	-	6	-	13	6	-	75
203	-	-	-	25	-	-	75

Table 30

Monthly percentage of unisexual female and hermaphrodite individuals of *P. heptadactylus* during the period October 1958 to October 1959.

Month	O	N	D	J	F	M	A	M	J	J	A	S	O
Unisexual female (%)	97	73	90	76	81	70	78	41	70	92	89	75	53
Hermaphrodite (%)	3	27	10	24	19	30	22	59	30	8	11	25	47

Table 31

Monthly percentage of unisexual male and hermaphrodite individuals of *P. heptadactylus* during the period October 1958 to October 1959.

Month	O	N	D	J	F	M	A	M	J	J	A	S	O
Unisexual male (%)	93	60	86	67	44	12	44	56	52	33	62	26	8
Hermaphrodite (%)	7	40	14	33	56	88	56	44	48	67	38	74	92

individuals increased with the size. Most of them in stage II in the higher lengths were spent recovering ones. It is interesting to note that the largest of hermaphrodites recorded here being 207 mm in furcal length, they appear to grow upto the size of the largest unisexual male which measured 210 mm.

The relation of the hermaphrodites to the unisexual females as in Table 30 shows that the latter predominated during all the months excepting in May when the former (59%) surpassed the latter (41%). In the rest of the months the percentgges of the hermaphrodites ranged between 3 in October 1958 and 47 in October 1959. In contrast to the above the unisexual males as seen in Table 31, did not exceed the hermaphrodites in numbers all through. In certain months unisexual males predominated while in others the hermaphrodites. The hermaphrodites surpassed the unisexual males in number, the percentage occurrence of the former being 56 in February, 88 in March, 56 in April, 67 in July, 74 in September and 92 in October.

The high percentage in which the hermaphrodites in P.heptadactylus occur in most of the months, explains a normal, but not a teratlogical phenomenon. The simultaneous development of both the sex elements in hermaphrodites and also the appearance of spent individuals wherein both ova and sperms are shed proves that this species is a synchronous hermaphrodite and not a gonochoritic one. Further the high percentage in which these hermaphrodites occur, sometimes surpassing even the males in number, leads one to believe that they are functional.

Hermaphrodites are similar to males in that their relative proportions in the samples are very close; they also appear to grow to more or less the same maximum size, as shown by the largest individuals measured under the said groups. Ova of hermaphrodites have similar maturity stages as of unisexual females. Since both the ovarian and testicular parts in an ovotestis become spent at the same time and considering the hermaphrodites as functional for the above mentioned reasons, there may be a possibility of self-fertilization in _P. heptadactylus_. Though the hermaphrodites like males have not been obtained in higher lengths, the fact that they are encountered from the smallest size when the sexes can be differentiated, till the largest size, along with the unisexual males and females, rules out the possibility of sex reversal in this fish. In cases, where sex reversal in fishes is known, the individuals upto a certain age and length function as one sex, after which they change to opposite sex with a short period of intersex in between.

According to Witschi (1932) as mentioned by D'Ancona (loc.cit.) and Liu and Ku (loc.cit.) sex differentiation has a double origin, cortex derived from the peritoneal wall giving rise to ova and medulla from the internal blastema giving rise to spermatozoa by the respective female and male inducing factors. D'Ancona states that the somatic substratum of the gonad has a simple origin from the peritoneal wall. He has observed spatial separation of the ovarian and testicular parts in a number of teleosts and believed that the somatic tissue of the gonad, which is chemodifferentiated into different regions by the male and female inducing substances, produces sexually different male and female germ cells in the corresponding regions. Essenberg (loc.cit.) has found that during sex reversal in Xiphophorus helleri, the epithelium of the ovarian cavity gives rise to oocytes first and spermatocytes later.

In accordance with Witschi's view the sexually indifferent primordial germ cells are first in the peripheral cortex; if they remain there they develop into ova but if they migrate to the central medulla they develop into spermatozoa. In P.heptadactylus, the ovarian part occupies a greater area and the ovarian lamellae with oocytes are seen all around whereas the testicular part occupies comparatively a smaller area and the spermatocytes in it begin to develop from the septum separating it from the ovarian part and proceed further to the periphery. Here the cortex and the medullary portions cannot be identified. The development of sex elements in P.heptadactylus is from the somatic substratum as observed by Essenberg (loc.cit.), D'Ancona (loc.cit.) and Liu and Ku (loc.cit.) in other forms.

Liu (loc.cit.) has found Monopterus javanensis changing with regularity from female to male and considered it to be a developmental gonochorist rather than a hereditory gonochorist, the hermaphroditic condition being merely in time during the short period of sex transormation. He has further stated that in the evolutionary stages, this species as a developmental gonochorist, bridges the gap between the functional and rudimentary hermaphrodites.

Differentiation of greater number of unisexual males and females and also a smaller number of hermaphrodites that appear to be functional indicates that *P.heptadactylus* is still primitive in the process of its evolution and has not yet reached a state of sexual stability in its reproductive function.

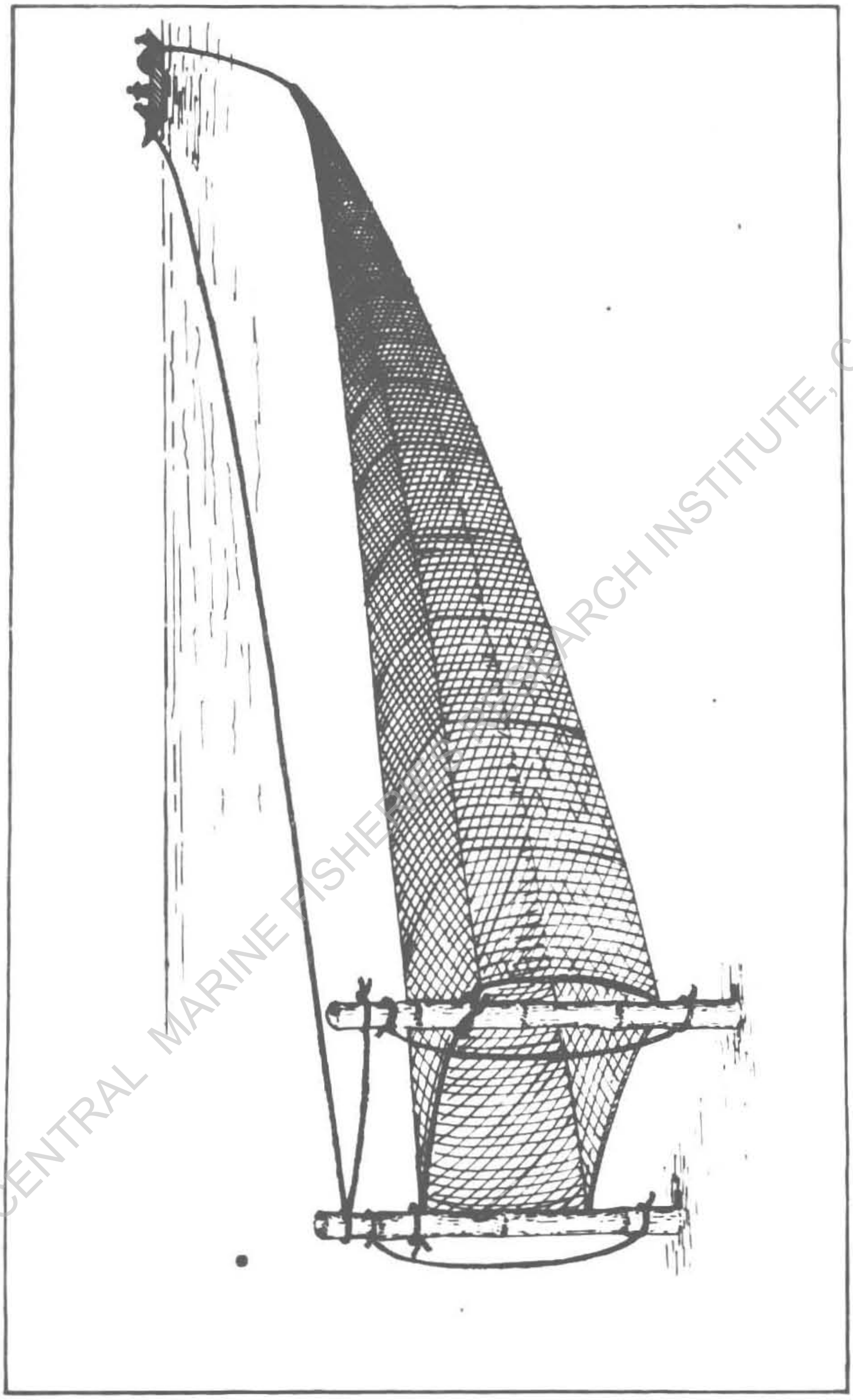
PART - III

FISHERY

The average annual landings of Polynemid fishes in India for the period of eight years from 1950 to 1957, have been estimated at 5,097 metric tons which works out to 0.82% of the total landings of all fish (Banerji, 1958). Three important commercial species, namely, *Eleutheronema tetradactylum*, *Polynemus indicus* and *P. heptadactylus* from the north western part of India, contribute to the major portion of the fishery. The report on the marketing of fish in the Indian Union (1961) shows that the Indian salmon (*E. tetradactylum*) has contributed 1.3% or 125.8 thousands of maunds to the sea and estuarine fishes landed in the country; of these, 48.4 thousand maunds have been fished from the Bombay coast forming 3.23% of the total catch. The magnitude of the catch of *P. indicus* in the Bombay and Saurashtra waters can be judged from the works of Mohamed (1955), Jayaraman *et al* (1959) and Nayak (1959d). Deshpande (1962) has given an account of 'Dara' with particular reference to its fishing methods along the Bombay coast. Though *P. heptadactylus* is seen to occur in good quantities in these inshore and offshore waters, no published account on the fishery of this species is available. The introduction of the New India Fisheries Company's bull-trawlers in the Bombay and Saurashtra waters and the maintenance of the catch data in detail by their skippers for *P. heptadactylus*, gave the author an opportunity to know in detail about its fishery.

P. heptadactylus or 'Shende' is obtained throughout the year in Bombay and is landed by two types of gear, the 'Dol' or bag

88. [illegible] 'il' net



nets and trawl nets as already stated. The operations of 'Dol' are carried out by the local fishermen from the ages past in the inshore waters, in the vicinities of Sassoon Docks, Versova, Danda, Worli and other fishing villages. The motor fishing boats 'Champa', 'Bumili' and 'Bangda' of the Government of India Deep Sea Fishing Station, Bombay, operated otter trawls at the mouth of the Bombay harbour whereas the two sets of trawlers, 'Arnalla'-'Paj' and 'Satpati'-'Pilotan' belonging to the New India Fisheries Company, operated bull-trawls in the offshore waters of Bombay and Saurashtra.

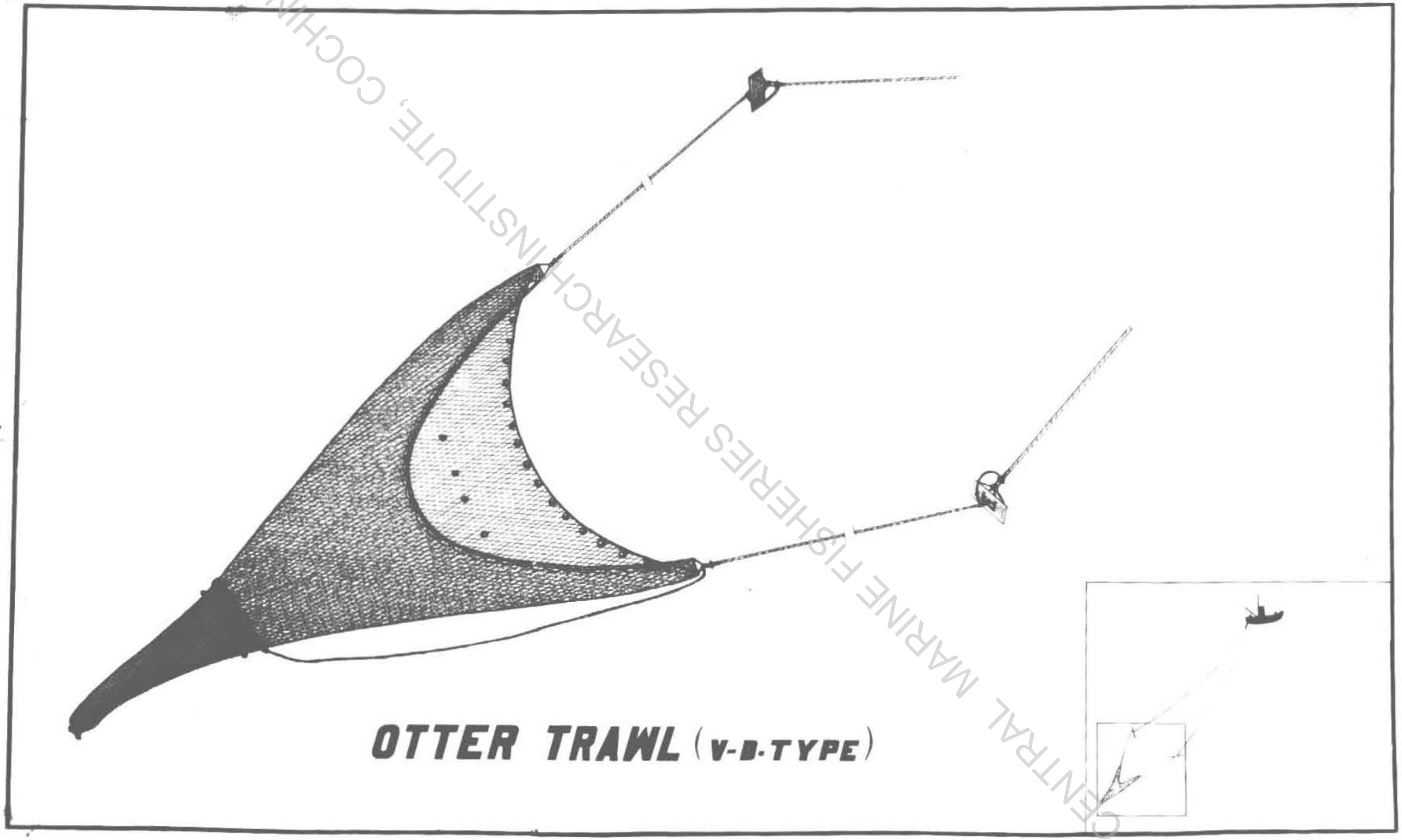
The 'Dol', a large stationary net (Fig. 39) which is commonly used along the Bombay coast is conical, measuring 43-46 meters in length with a breadth of 30 metres at the mouth and a little less than a meter at the tail end, the mesh of the net varying from 127 mm at the mouth to 12.7 mm at the cod end. It is fixed to stakes in the tidal regions facing the incoming currents at depths of 15-45 meters with the help of sail boats or mechanised boats. The net is operated mainly by the tidal force (Setna, 1949). During the high tide, fishes enter the net as the water passes through it. When the tide recedes, the position of the net is reversed, its open end facing the opposite direction. In both the positions, the fishes are driven into the net by the force of current. Where the currents are strong to keep the net in horizontal position, sinkers and floats are used. It is operated often upto a distance of 20 miles from the shore. It differs from a trawl net in being stationary and its

Table 32

The Government of India Fishing Vessels: Some specifications and Gear used

Particulars	Vessels		
	M.F.V. 'Bangada'	M.F.V. 'Champa'	M.F.V. 'Bumili'
Overall length (metres)	15.74	15.24	15.24
Beam (metres)	5.26	5.06	5.06
Draft (metres)	2.90	1.68	1.68
Gross Tonnage (metric tons)	52.53	50.80	50.80
Net Tonnage (metric tons)	15.24	10.16	10.16
BHP	215	165	135
Gear	Otter-trawl	Otter-trawl	Otter-trawl
Length of head rope	39.19m.	-	-
Length of foot rope	49.38m.	-	-
Length of Hunt rope	100.58 - 118.87 m.	-	-
Size of cod end mesh	63.5 mm.	-	-

40. Otter-trawl


OTTER TRAWL (V-D-TYPE)

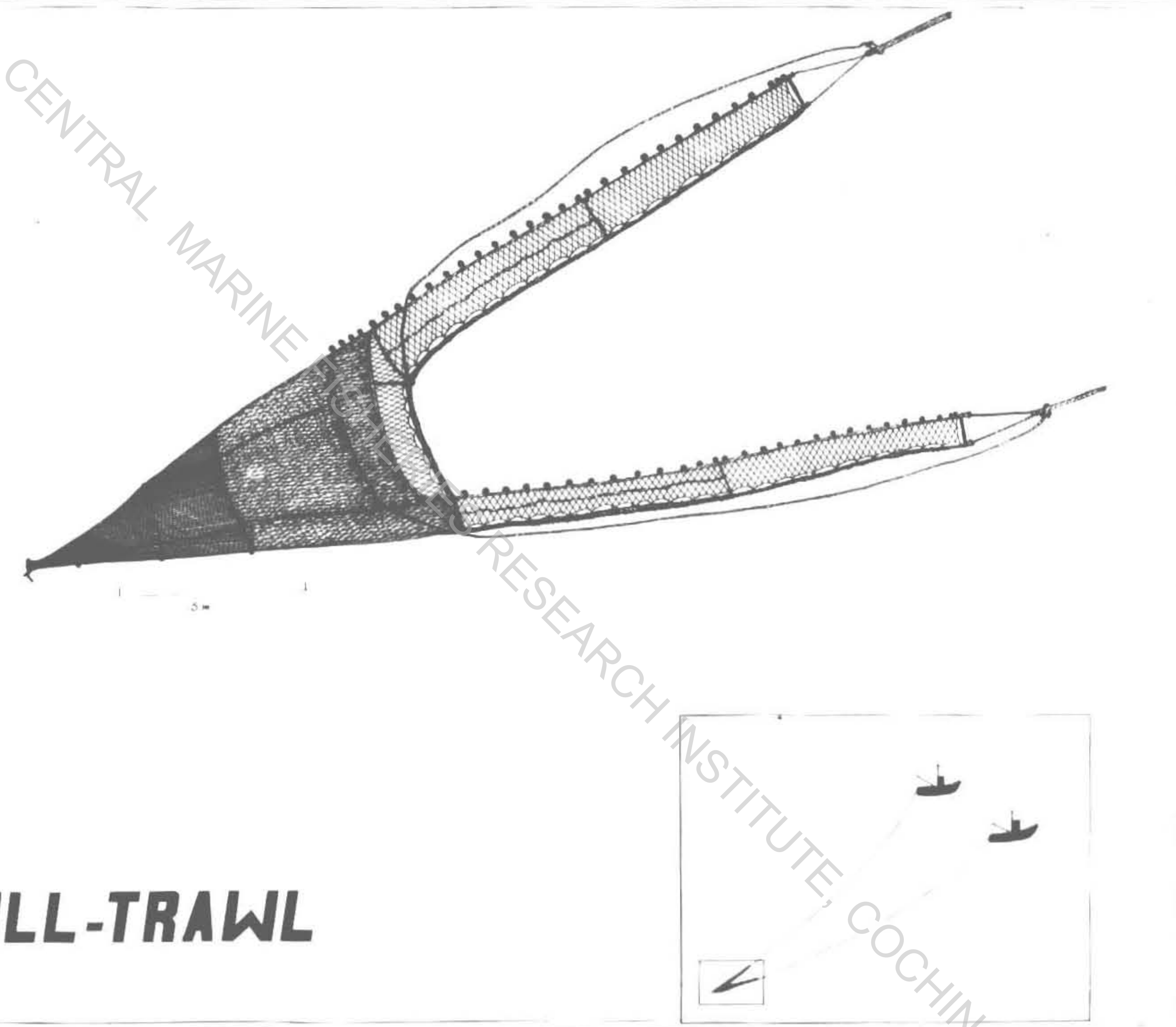
catch consists of fishes from shallower waters.

During monsoon months very close to the shore a miniature type of 'Dol' called 'Bokshi' is operated in the very shallow waters. The catches obtained therefrom are erratic and meagre.

The otter trawl (Fig. 40) is a bottom trawl where the wings of the net are spread with the help of a pair of otter boards, one on each side, which tend to diverge outward and keep the mouth of the net open. The Government of India vessels used Vigneron-Dahl type of otter trawls, with otter boards attached at some distance from the wings to increase the speed of the net. Details of the Government of India vessels and the gear used by them are given in Table 32 and Fig. 42b. They operated at depths ranging from 11 to 36 meters in almost all months of the year except during the monsoon.

The bull-trawl (Fig. 41) also a bottom trawl, is operated by a pair of vessels. Two towing lines are attached to the mouth of the net and each of the lines is towed by a vessel. The vessels maintain a certain distance between them in order to spread the wings of the net fully. Shooting and hauling of the net are done alternately by each of the vessels. Details of the New India Fisheries bull-trawlers and the gear used by them are given in Table 33 and Fig. 42a. These vessels operated throughout the year at depths between 21-87 meters. The bull-trawl differs from the otter-trawl in the absence of otter boards, in being a much larger

41. Bull-trawl



BULL-TRAWL

Table 33

Details of the New India Fisheries Bull-trawler and the Gear used by them

Particulars	VESSELS			
	'Satpati'	'Pilotan'	'Arnalla'	'Paj'
Overall length (metres)	29.19	29.11	29.31	29.24
Beam (metres)	5	5	5	5
Draft (metres)	1.8/2.4	1.8/2.4	1.8/2.4	1.8/2.4
Gross Tonnage (metric tons)	93.18	94.16	94.16	94.16
Net tonnage (metric tons)	44.87	45.78	45.78	45.78
Engine	Diesel, Kobe Akasa, Japan			
Engine Power B.H.P.	250	250	250	250
Auxiliary Engine	Yanmar Diesel			
Auxiliary Engine B.H.P.	20	20	20	20
Winch Capacity (metric tons)	4.06	4.06	4.06	4.06
Number of men	16-17	15-16	16-17	15-16
Type of net	Bull-trawl	Bull-trawl	Bull-trawl	Bull-trawl
Length of Head rope (metres)	67.06	67.06	67.06	67.06
Length of Foot rope (metres)	68.58	68.58	68.58	68.58
Mesh of belly & beating (cms.)	8.89	8.89	8.89	8.89
Mesh at cod end (cms.)	5.08	5.08	5.08	5.08

42. a New India Fisheries bull-trawlers, 'Arnalla' – 'Raj'.

b Government of India Fishing vessel, M.F.V. 'Bumili'


ARNALLA
PAJ

sized net and in the presence of very long hunt rope.

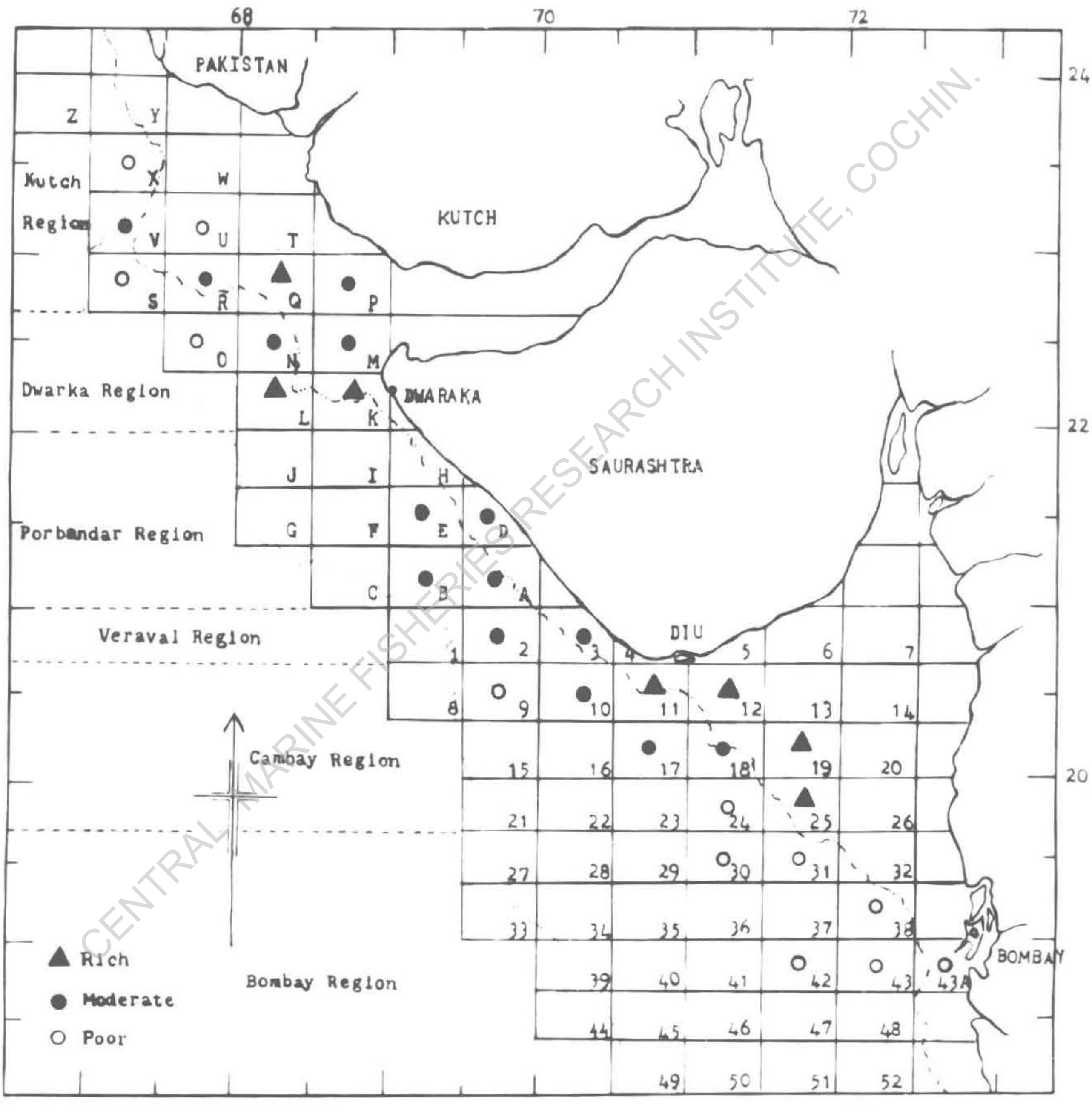
The catch of P.heptadactylus from 'Dol' nets and to a greater extent from the otter trawls, was dominated by the juveniles not exceeding 80-90 mm in length, and these were seldom marketed fresh, but mostly sundried along with shrimps and other smaller varieties of fishes. The catches from these two sources were meagre and for want of precise data no estimate of their total landings could be made.

The bull-trawlers landed large sized adults in appreciable numbers throughout the year. During their continuous fishing for about eight years in the Bombay and Saurashtra waters from April 1956 to October 1963, 'Shende' contributed to on an annual average of 3% to the total catch. During monsoon months, this fish fetched good price in Bombay markets and was always preferred to small sciaenids, locally called 'Dhoma'. A detailed account of the catch of Polynemus heptadactylus by the bull-trawlers is given here.

Fishing Grounds

The New India Fisheries bull-trawlers fished in the same grounds as the Government of India Cutters M.T.'Ashok' and M.T.'Pratap' did during their exploratory fishing operations in the Bombay and Saurashtra waters (Jayaraman et al, loc.cit.). The unit fishing areas of 600 nautical square miles each, based on 30 minute latitude by 20 minute longitude, are either numbered serially or lettered alphabetically and grouped into 6 regions in

43. Relative abundance of *P. heptadactylus* as revealed by catch-per-hour yields in different areas.



68
70
72
24
22
20
PAKISTAN
KUTCH
Kutch Region
Dwarka Region
DWARAKA
SAURASHTRA
Porbandar Region
Veraval Region
DIU
Cambay Region
Bombay Region
BOMBAY
Rich
Moderate
Poor

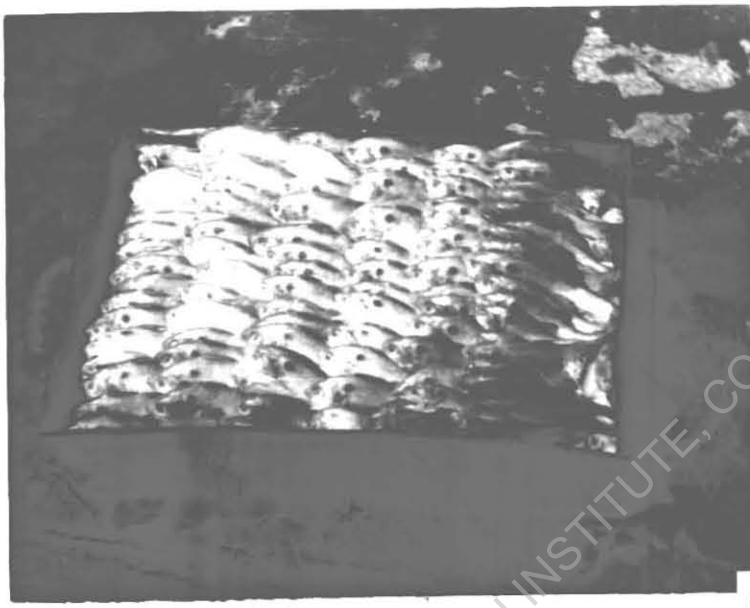
these waters (Fig.43). The regions with their corresponding areas fished by M.T.'Ashok' and M.T.'Pratap' are (1) Bombay region: '48', '43', '38', '32', '31', '30'; (2) Cambay region: '26', '25', '24', '20', '19' '18', '17', '11', '10'; (3) Veraval region: '4', '3', '2'; (4) Porbandar region: 'A', 'B', 'D', 'E', 'H'; (5) Dwarka region: 'K', 'L', 'M', 'N'. The bull-trawlers fished in all the above mentioned areas of the Bombay region and also in the areas '43A', '42', '37' and '36'; in the Cambay region they did not operate in the areas '26' and '20' but fished in '23', '16', '13', '12' and '9'; the new grounds touched in the Veraval region was '1' and in Porbunder 'G' and 'I'. The Cutters did not extend their fishing beyond Dwarka region whereas the bull trawlers fished in the northernmost areas 'P' to 'Z' of the sixth region, viz. Kutch.

Analysis of the Catch

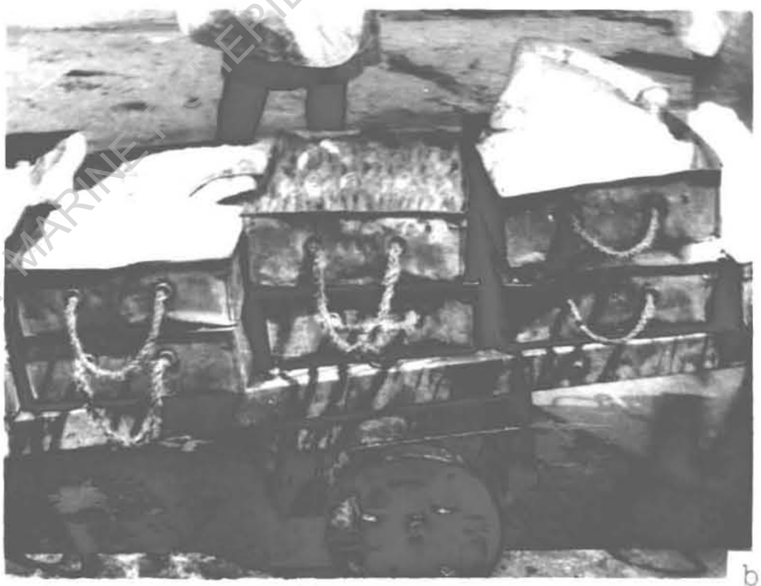
The log books of the new India Fisheries trawlers recorded the landings of small fishes by the number of cases and of large ones by the number of pieces. The case of 58 cm x 36 cm x 12½ cms is made of wood or metal (Fig.44). Pieces are sorted into big and ordinary fish depending on their lengths. A fish measuring roughly above 90 mm is classified as big fish and below that to 60 mm as of ordinary size. All fish smaller than these are put in cases. For estimating the weight of the total catch, units of weights allotted for cases and individual pieces are given below:

44. _P. heptadactylus_: a) arranged in cases landed by bull-trawlers,

b) cases loaded on hand-carts.



a



b

Items	Weight (Kg.)
Case............................	18
Big 'Dara' (Polydactylus indicus)..	9
'Dara' or	
'Chelna' "= " ..	7
Big 'Rawas' (Eleutheronema tetradactylum)	7
'Rawas' " "	5
Big 'Ghol' (Pseudosciaena diacanthus)..	9
'Ghol' " " ..	7
Big 'Koth' (Otolithoides brunneus).....	11
'Koth' " "	7
'Singala' (Catfish).....................	4
'Tam' (Lutianus spp.)...................	3
Big Shark...............................	70
Shark...............................	45
Saw fish................................	75
'Ekhru' (Epinephelus spp.)..............	30
Barracuda (Sphyraena spp.)..............	8
'Surmai' (Cybium spp.)..................	6

The haul-wise, area-wise and depth-wise entry of the catch data in the log books were processed to know about the catch, effort and seasonal variation in the catch; regional, area-wise and depth-wise distribution; and the influence of tides and lunar phases on the catches of *P. heptadactylus*. The catch rate or the catch in Kg. per hour of trawling has been used as a measure of determining the relative productivity of the different grounds or the relative abundance of the yields in different seasons or in different depth zones.

Fishing Efforts

The effort put in any trawl fishing is the time interval between the shooting of the net and hauling it. The time spent for each haul ranged from 1 to 3 hours, but the majority of hauls were for 1 hour and 15 minutes. Table 34 shows the total number of hauls taken and those with P. heptadactylus during different months in the six regions from April 1957 to March 1959. The number of hauls taken from all the regions, excepting Dwarka and Kutch were more in the first year than in the second. The maximum of 1,556 hauls in the first year and 1,285 in the second were taken from Cambay region. The minimum of 2 hauls in the first year were taken from Kutch region and 45 in the second year from Bombay region. Next to Cambay came Porbandar, Dwarka and Veraval the hauls taken from them being 1,212, 675 and 484 in the first year and 1,002, 729 and 433 in the second year.

The table also shows that in all the regions excepting Bombay, more than 50% of the hauls in a year yielded P. heptadactylus. Bombay showed this species in 10% of the hauls taken in the first year and 20% in the second year. The only two hauls taken from the Kutch region in the first year recorded P. heptadactylus. The highest percentage of hauls with this species was from Dwarka region forming 73% and this was followed by Porbundar, Cambay and Veraval with 68%, 67% and 54% respectively. In the second

Table

Number of hauls and hauls with *P. heptadactylus* or 'Shende' (%) taken from

1957-58

Month	Bombay		Cambay		Veraval		Porbundar		Dwarka		Kutch	
	No. of hauls	No. of hauls with Shende	No. of hauls	No. of hauls with Shende	No. of hauls	No. of hauls with Shende	No. of hauls	No. of hauls with Shende	No. of hauls	No. of hauls with Shende	No. of hauls	Sh
April	3	0	79	65 (82)	2	1 (50)	211	159 (75)	37	37 (100)	-	
May	14	2 (14)	105	98 (93)	5	4 (80)	38	21 (55)	-	-	-	
June	1	1 (100)	235	184 (78)	124	73 (59)	5	4 (80)	-	-	-	
July	2	0	176	92 (52)	112	43 (38)	70	49 (70)	-	-	-	
August	2	0	330	274 (83)	18	14 (78)	-	-	-	-	-	
Septmmber	26	0	258	148 (57)	6	3 (50)	2	0	-	-	-	
October	2	0	173	85 (49)	8	0	57	0	60	23 (38)	-	
November	-	-	5	2 (40)	5	1 (20)	104	88 (85)	220	153 (69)	-	
December	-	-	36	13 (36)	74	30 (40)	194	121 (62)	82	56 (68)	2	(1
January	-	-	26	14 (54)	47	37 (79)	223	182 (82)	85	75 (88)	-	
February	6	1 (17)	83	20 (24)	59	33 (56)	97	60 (62)	120	103 (86)	-	
March	11	3 (27)	50	47 (94)	24	22 (92)	211	140 (66)	71	44 (62)	-	
Total	67	7	1556	1042	484	261	1212	824	675	491	2	
Percentage		10		67		54		68		73		1

34

ifferent regions by the New India Fisheries Trawlers for the period 1957-1959.

1958-59

Bombay	Cambay		Veraval		Porbundar		Dwarka		Kutch	
No. of hauls with Shende	No.of hauls	No.of hauls with Shende	No.of hauls	No.of hauls with Shende	No.of hauls	No.of hauls with Shende	No.of hauls	No.of hauls with Shende	No.of hauls	No.of hauls with Shende
0	94	86 (91)	6	5 (88)	63	30 (48)	-	-	-	-
0	99	94 (95)	16	13 (82)	117	83 (71)	-	-	-	-
1 (8)	51	42 (82)	36	9 (25)	48	24 (50)	-	-	-	-
0	88	8 (9)	169	112 (66)	84	69 (82)	-	-	-	-
0	266	171 (64)	62	24 (39)	-	-	-	-	-	-
3 (30)	266	250 (94)	22	13 (59)	-	-	-	-	-	-
5 (42)	245	232 (95)	1	0	2	0	23	28 (78)	-	-
0	2	2 (100)	-	-	77	48 (62)	191	162 (85)	21	8 (38)
-	14	6 (43)	45	36 (80)	185	150 (81)	120	86 (72)	4	4 (100)
-	66	54 (82)	37	24 (65)	211	128 (61)	63	49 (78)	-	-
0	61	52 (85)	21	16 (76)	114	65 (57)	150	115 (77)	-	-
0	33	23 (69)	18	17 (94)	101	60 (59)	182	140 (77)	40	27 (68)
9	1285	1020	433	269	1002	657	729	570	65	39
20		79		62		66		78		60

year, Cambay showed the maximum of 79% of hauls in which this species was present, followed by Dwarka, Porbundar, Veraval and Kutch showing 77%, 66%, 62% and 60% respectively.

Table 35 shows the number of trips, hauls and percentage of hauls with P.heptadactylus for each of the areas in six regions. In Bombay region 5 areas were visited in the first year and 4 in the second. The areas '38', '43' and '43A' had the hauls ranging between 2 and 38 in the two years and 8% to 27% of them recorded P.heptadactylus. The areas '42', '31' and '30' were the least exploited and did not show this species in their hauls.

Of the areas fished in the Cambay region, '9' was not visited in the second year. The areas '10' and '11' were visited frequently and a good number of hauls from each viz. 181 to 602 were taken in the two years. The areas '25' '24', '18', '17' and '12' were visited less frequently and the hauls from them were ranging between 11 from the area '24' and 134 from '18' in the second year. Areas '19' and '9' were the least exploited and the latter recorded no P.heptadactylus. Excepting in two cases, in all areas more than 50% of the hauls recorded this species in the two years.

In Veraval region, in both the years the area '3' was visited more frequently than '2', but the number of hauls taken from them did not differ greatly; 51% to 69% of the hauls

Table 35

Number of trips, hauls and percentage of hauls with *P. heptadactylus* in areas fished under different regions by New India Fisheries trawlers during 1957-59

BOMBAY

	1957-58						1958-59					
Areas	43A	43	42	38	31	30	43A	43	42	38	31	30
No. of trips	4	6	1	6	2	-	2	8	-	12	-	1
No. of hauls	13	11	3	38	3	-	2	17	-	26	-	1
Percentage of hauls with *P. heptadactylus*	8	18	0	11	0	-	0	12	-	27	-	0

CAMBAY

Areas	25	24	19	18	17	12	11	10	9	25	24	19	18	17	12	11	10	9
No. of trips	6	8	1	14	12	4	48	23	1	1	4	1	9	16	9	52	17	-
No. of hauls	38	92	2	134	71	75	491	602	1	3	11	7	93	100	75	814	181	-
Percentage of hauls with *P. heptadactylus*	16	26	50	60	71	63	75	76	0	100	82	100	92	84	95	81	55	-

VERAVAL

Areas	3	2	3	2
No. of trips	34	11	33	12
No. of hauls	251	233	188	244
Percentage of hauls with *P. heptadactylus*	57	51	69	57

Table 35 contd..

PORBUNDAR

1957-58 A	1957-58 B	1957-58 D	1957-58 E	Areas	1958-59 A	1958-59 B	1958-59 D	1958-59 E
39	3	15	17	No. of trips	34	4	22	10
944	19	130	119	No. of hauls	660	40	157	116
72	68	65	58	Percentage of hauls with *P. heptadactylus*	64	88	77	72

DWARKA

1957-58 K	1957-58 L	1957-58 M	1957-58 N	Areas	1958-59 K	1958-59 L	1958-59 M	1958-59 N
19	9	22	15	No. of trips	21	5	23	19
126	34	336	164	No. of hauls	286	13	192	238
74	91	68	76	Percentage of hauls with *P. heptadactylus*	72	62	74	89

KUTCH

1957-58 P	1957-58 Q	1957-58 R	1957-58 S	1957-58 U	1957-58 V	1957-58 X	Areas	1958-59 P	1958-59 Q	1958-59 R	1958-59 S	1958-59 U	1958-59 V	1958-59 X
1	1	-	-	-	-	-	No. of trips	-	2	3	1	1	3	1
1	1	-	-	-	-	-	No. of hauls	-	19	13	1	2	28	2
100	100	-	-	-	-	-	Percentage of hauls with *P. heptadactylus*	-	95	62	100	0	43	0

recorded this species.

In Porbundar region the fishing trips to the area 'A' were frequent and the number of hauls tkken from it were the highest; 'B' had been fished least in both the years. All the 4 areas recorded *P. heptadactylus* in good number of hauls forming about 58% to 88% in the two years.

In Dwarka region more trips were made to the areas 'K', 'M' and 'N' and the hauls taken from them were also more than from 'L' in both the years. In all these 4 areas 62% to 91% of the hauls recorded this species.

In Kutch region the areas 'P' and 'Q' only were visited in the first year and excepting 'P' all the rest in the second year. Of these the areas 'Q', 'R' and 'V' were exploited more than others and 43% to 95% of the hauls from them had *P. heptadactylus*. Only one haul from each of the areas 'P', 'Q' and 'S' was taken recording this species, which was however absent from either 'U' or 'X' in any of the hauls.

Thus during the period of observation, from April 1957 to March 1959 Bombay region was found to be very poorly exploited. The maximum number of trips made and the hauls taken from the areas '43' and '38' yielded a very small percentage of hauls with *P. heptadactylus*. In the Cambay region the areas '11' and '10' were

Table

Number of fishing hours in different months by the New India tr

1957-58

Month	Bombay	Cambay	Veraval	Porbundar	Dwarka	Kut
April	4.6	114.3	3.1	306.8	53.8	-
May	20.5	149.7	7.9	54.8	-	-
June	1.5	332.8	169.3	7.8	-	-
July	3.1	249.8	159.5	91.1	-	-
August	2.6	479.9	25.8	-	-	-
September	36.9	372.7	7.9	2.7	-	-
October	2.5	249.4	11.6	80.9	86.6	-
November	-	7.1	6.4	150.6	320.4	-
December	-	50.5	107.4	286.1	121.6	2.[illegible]
January	-	35.3	68.9	321.8	122.4	-
February	9.6	44.9	87.1	140.4	175.5	-
March	16.4	69.7	35.7	309.3	103.9	-
Total	97.7	2,156.1	690.6	1,753.3	984.2	2.[illegible]

36

lers in different regions for the period 1957-59.

1958-59

Bombay	Cambay	Veraval	Porbundar	Dwarka	Kutch
7.9	137.3	8.0	92.3	-	-
3.6	149.2	24.9	178.4	-	-
18.4	56.4	50.7	70.1	-	-
1.3	126.6	245.3	123.6	-	-
1.3	393.5	92.8	-	-	-
13.7	397.4	33.3	-	-	-
17.5	356.3	1.2	1.8	32.8	-
1.2	3.6	-	116.1	284.2	30.6
-	18.2	65.1	271.1	176.5	5.9
-	97.0	51.8	316.5	92.9	-
2.2	87.6	32.0	169.9	224.3	-
2.5	46.5	26.5	154.0	269.9	58.6
69.6	1,869.6	631.6	1,493.8	1,080.6	95.1

fished intensively with maximum number of trips and hauls and it was also seen that majority of the hauls taken were with this fish. To other areas though the number of trips made was much less, the percentages of hauls with this fish were quite good. In Veraval region both the areas '3' and '2' were intensely fished, but the former had higher percentage of hauls with this fish. In Porbundar region the area 'A' was fished the maximum and 'B', the minimum and all the areas recorded a good percentage of hauls with this species. In Dwarka region in all the areas the percentages of hauls with P.heptadactylus were high. In the Kutch region all the areas excepting 'U' and 'X' showed fairly high percentages of hauls with P.heptadactylus.

It can be seen from the Table 36 that the maximum effort of 2,156.1 hours was put in Cambay region during the first year of fishing. This was followed by Porbundar with 1,753.3 Dwarka with 984.2, Veraval with 690.6, Bombay with 97.7 and Kutch with 2.6 hours of fishing. In the second year of fishing, 1,869.6 hours were spent in Cambay and 1,493.8 in Porbandar, 1,080.6 in Dwarka, 631.6 in Veraval, 95.1 in Kutch and 69.6 hours in Bombay region.

Catch

In the total average annual catch of 3,284,453 kg. for all fish from the bull-trawlers in Bombay and Saurashtra waters for the period of 8 years from April 1956 to October 1963,

Table 37

Annual Regional distribution of *P. heptadactylus* in the landings of New India Fisheries bull-trawlers

Year	All Regions Catch in kg (Kg per hour) %	Bombay Catch in kg (Kg per hour) %	Cambay Catch in kg (Kg per hour) %	Veraval Catch in kg (Kg per hr.) %	Porbandar Catch in kg (Kg. per hr.) %	Dwarka Catch in kg (Kg. per hr.) %	Kutch Catch in kg (Kg. per hr.) %
1956	22,698 (7.96) 0.99	2,430 (3.51) 0.49	16,488 (13.03) 1.50	0	18 (0.40) 0.10	3,762 (5.04) 0.63	-
1957	147,294 (27.01) 4.49	72 (0.95) 0.30	77,238 (38.42) 6.00	11,988 (22.86) 4.36	33,732 (23.65) 3.75	24,174 (17.30) 3.07	90 (33.83) 4.75
1958	157,608* (31.25) 4.43	180 (2.26) 0.67	70,074 (40.02) 5.36	13,662 (19.75) 3.10	33,372 (20.92) 2.97	39,834 (44.96) 6.24	342 (9.20) 1.90
1959	102,150 (23.75) 3.76	414 (4.46) 1.12	28,908 (22.58) 4.21	12,654 (24.96) 4.46	13,122 (14.44) 2.46	20,070 (24.14) 4.16	26,982 (39.58) 3.87
1960	133,460 (25.86) 3.15	0	2,592 (17.95) 3.81	4,914 (12.72) 2.14	8,154 (8.98) 1.25	13,428 (36.41) 5.06	104,372 (31.23) 3.45
1961	104,400 (22.61) 2.65	72 (41.14) 16.32	5,580 (8.52) 1.48	4,788 (11.62) 1.66	7,794 (11.94) 1.57	10,548 (44.16) 5.29	75,618 (28.45) 2.94
1962	48,492 (12.27) 1.37	0	2,610 (3.61) 0.41	1,224 (4.64) 0.74	3,978 (4.30) 0.50	2,556 (18.20) 2.17	38,124 (20.21) 2.08
1963	43,680 (12.29) 1.63	0	3,105 (4.12) 0.64	5,670 (16.11) 2.51	4,626 (4.70) 0.66	4,806 (40.50) 4.74	25,473 (19.12) 2.20
Average	94,973 (21.74) 2.89	396 (3.24) 0.53	25,824 (24.11) 3.52	6,863 (17.04) 2.80	13,100 (14.03) 2.13	14,897 (25.15) 3.74	38,714 (26.92) 2.87

* includes 144 kg from an unclassified area

P.heptadactylus comprised 94,973 kg forming 2.89% at a catch rate of 21.74 kg per hour of trawling (Table 37). The highest catch of 157,608 kg with the highest catch rate of 31.25 kg per hour of fishing was in 1958 when it formed 4.43% and the lowest catch of 22,698 kg with the lowest catch rate of 7.96 kg per hour and the lowest percentage of 0.99 was in 1956 which was the year when the fishing by these vessels was started. There was no fishing for the first 3 months which explains the reason for the low catch obtained. The highest percentage of 4.49 for *P.heptadactylus* was obtained in 1957 when the catch was 147,294 kg with a catch rate of 27.01 kg per hour. The annual catch and its percentage showed a gradual decline year after year from 1958. The decline in the catch appears to be roughly by 1% and 10 kg per hour of fishing in every alternate year. In 1963, when there was no fishing in the last two months, the catch showed a slight increase in the percentage from that of the previous year. The catch in 1963 was 43,680 kg with the catch rate of 12.29 kg per hour forming 1.63% but in 1962 the catch was slightly better being 48,492 kg although the catch rate and percentage were lower being 12.27 kg per hour and 1.37% respectively. The regional abundance of the catch is dealt with in the following account.

Kutch recorded the highest average annual catch of 38,714 kg of *P.heptadactylus* with the highest catch rate of 26.92 kg per hour, but ranked only third by percentage with 2.87%. The highest average annual percentage catch of 3.74 with the catch rate of 25.15 kg per hour was from Dwarka region. Cambay ranked second in the average annual catch of 25,824 kg and the percentage catch of 3.52, but ranked third with the average annual catch rate of

24.11 kg per hour. This was followed by Porbundar in the average annual catch only but by Veraval in the average annual percentage catch and the catch rate. The catch in Porbundar was 13,100 kg, catch rate 14.03 kg per hour and percentage catch 2.13, whereas in Veraval the average annual catch was 6,863 kg, catch rate 17.04 kg per hour and percentage catch 2.80. Bombay was the poorest of all regions for this species with the lowest average annual catch of 396 kg, catch rate of 3.24 kg per hour and percentage catch of 0.53.

From the above it is seen that Cambay, Dwarka and Kutch regions are found to be rich, Veraval and Porbundar moderately rich and Bombay poor for this species.

Bombay region, with the least productive trawling grounds for P.heptadactylus, did not yield this species in the 3 years of 1960, 1962 and 1963. However, in 1961 the smallest catch of 72 kg had the highest catch rate of 41.14 kg per hour with the highest percentage catch of 16.32. The highest catch of 2,430 kg forming 0.49% in 1956 showed a catch rate of 3.51 kg per hour.

In the Cambay region the highest catch of 77,238 kg had the highest percentage catch of 6 in 1957, but the catch rate of 38,42 kg per hour during that year was only next to 40.02 kg per hour of 1958 when the catch of 70,074 kg formed 5.36% of the total landings. The minimum catch of 2,610 kg, catch rate of 3.61 kg per hour and the percentage catch of 0.41 were observed in 1962. In the rest of the years the catch, catch rates and percentages of catch ranged between 3,105 kg, 4.12 kg per hour and 0.64 of 1963 and 28,908 kg, 22.58 kg per hour and 4.21 of 1959. This region showed a considerable fall in the catch and other catch details year after year not taking into account the catch of 1956 and this fall appears to be particularly significant from 1959 onwards. However, an improvement in the catch was indicated in 1963.

There was no record of *P.heptadactylus* in Veraval region in 1956. The yield of 13,662 kg was the maximum when the catch rate and the percentage catch were 19.75 kg per hour and 3.10 kg respectively in 1958; the catch rate of 24.96 kg per hour and the percentage catch of 4.46 were the maximum in 1959 when the catch was 12,654 kg. The fall in the catch and other details were marked from 1960 onwards, the lowest of 1,224 kg catch, 4.64 kg per hour of catch rate and 0.74 of percentage of catch being in 1962. There has been a very good increase in the catch in 1963 in this region also.

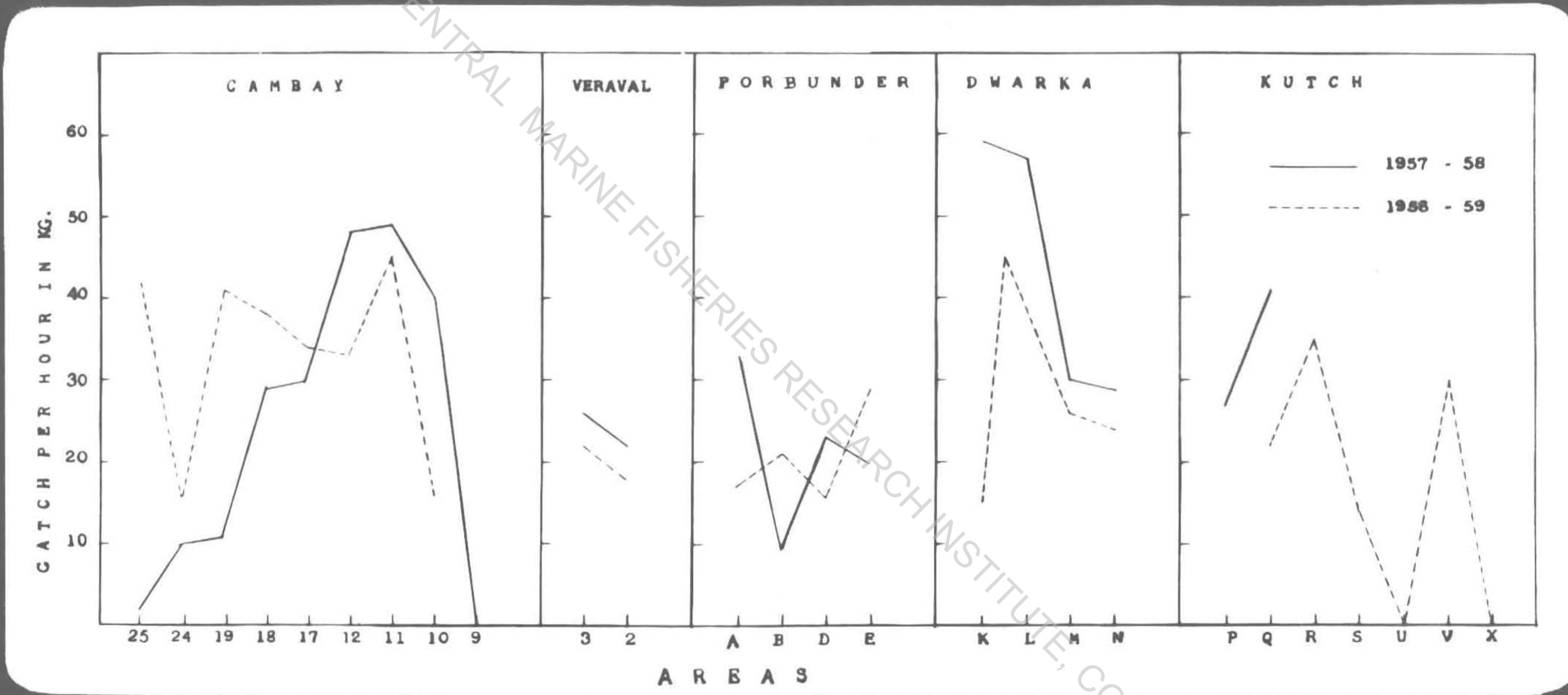
From Porbundar region the highest catch of 33,732 kg was in 1957 when the catch rate of 23.65 kg per hour and the percentage catch of 3.75 were also the highest. The catch, catch rate and percentage catch in the following year of 1958 being 33,372 kg, 20.92 kg per hour and 2.97%, were not significantly different from those of the previous year. Steady decline in the catch and other catch details of *P.heptadactylus* started in the years 1959 onwards in this region also with an indication towards their upward trend in 1963. The minimum catch of 3,978 kg, catch rate of 4.30 kg per hour and the percentage catch of 0.50, were in 1962.

Dwarka region, the richest by percentage catch, yielded a maximum catch of 39,834 kg, the catch rate of 44.96 kg per hour and the percentage catch of 6.24 in 1958. While the catch showed a decline in this region as in others from 1959 onwards, the annual catch rates and percentages of catch remained unsteady, the catch rates fluctuating between 18.20 kg per hour in 1962 and 44.16 kg per hour in 1961 and the percentage catch between 2.17 and 5.29 in the same years.

There was no fishing in the Kutch region in 1956. The intensity of fishing in this region increased from 1959 onwards. The highest catch of 104,372 kg was in 1960 giving a catch rate of 31.23 kg per hour and the percentage of 3.45. The highest catch rate of 39.58 kg per hour was in 1959 when the catch of 26,982 kg formed 3.87%. The highest percentage catch of 4.75 was in 1957 when the catch rate of 33.83 kg per hour was also very good for an extremely low catch of 90 kg in 1957. There was no marked decline in the catches in this region.

It can thus be stated that the catch was declining from 1959 onwards in Cambay and Porbundar regions and from 1960 onwards in Veraval region. However, in all these three regions there was an increase in the catch in 1963. Though the catches were falling in the successive years in Dwarka and Kutch regions,

45. Area-wise yields of P.heptadactylus catch in Kg per hour of fishing in different regions by the New India Fisheries trawlers during 1957-'59.


CAMBAY
VERAVAL
PORBUNDER
DWARKA
KUTCH
1957 - 58
1958 - 59
CATCH PER HOUR IN KG.
60
50
40
30
20
10
25 24 19 18 17 12 11 10 9
3 2
A B D E
K L M N
P Q R S U V X
AREAS

there was no marked decline in the catch rates and the percentage catches.

Relative Abundance of *P.heptadactylus* in Different areas

A detailed area-wise distribution of the catch is studied here for the period of two years from April 1957 to March 1959 and presented in Table 38 (Fig. 45). In a general way it may be stated that areas yielding 20 kg. or less per hour of trawling may be considered as poor, over 20 kg. upto 40 kg. as moderate and above that as rich grounds for *P. heptadactylus*. Areas under different regions with relative catch rates on the above basis are shown in Fig. 43. It may be noted that yields in any particular area will not be constantly high or low. The highest catch rate in one of the two years has been taken as the basis for determining the relative richness of the grounds.

From the catch data for the period of 8 years from April 1956 to October 1963, it is inferred that Bombay region is the poorest for *P.heptadactylus* with the annual catch which was nil or less than 500 kg excepting in 1956 when it was 2,430 kg. Hence the area-wise analysis for this region is not discussed in the following account.

In the Cambay region, area '11' yielded the maximum of 49 kg per hour for a catch of 33,210 kg in the first year and 45 kg per hour for the highest recorded catch of 53,010 kg in

Table 38

Area-wise distribution of P.heptadactylus in the different regions during 1957-1959.

Area	1957 - '58		1958 - '59	
	Catch in kg	Kg/hr	Catch in kg	Kg/hr
CAMBAY REGION				
25	108	2	198	42
24	1,350	10	216	16
19	36	11	414	41
18	5,562	29	5,076	38
17	2,898	30	4,410	34
12	5,094	48	3,510	33
11	33,210	49	53,010	45
10	34,830	40	4,032	16
9	0	0	-	-
VERAVAL REGION				
3	9,090	26	6,030	22
2	7,362	22	6,264	18
PORBUNDAR REGION				
A	39,348	33	15,624	17
B	72	9	1,188	21
D	4,176	23	3,654	16
E	3,600	20	6,426	29
DWARKA REGION				
K	10,548	59	6,516	15

contd...

Table 38 contd...

Area	1957 - '58		1958 - '59	
	Catch in kg	Kg/hr	Catch in kg	Kg/hr
DWARKA REGION Contd....				
L	2,682	57	900	45
M	14,688	30	7,416	26
N	7,812	29	8,778	24
KUTCH REGION				
P	36	27	-	-
Q	54	41	612	22
R	-	-	720	35
S	-	-	18	14
U	-	-	0	0
V	-	-	630	30
X	-	-	0	0

the second year. During the first year the highest catch of 34,830 kg was from the area '10' with a catch rate of 40 kg per hour, the next high catch rate of 48 kg per hour for a catch of 5,094 kg being from the area '12'. Areas '18' and '17' recorded good catches of 5,562 kg and 2,898 kg and catch rates of 29 kg and 30 kg per hour in the same order; '24' a catch of 1,350 kg with a poor catch rate of 10 kg per hour; '19' a poor catch of 36 kg with a catch rate of 11 kg per hour; '25', a poor catch of 108 kg with a very low catch rate of only 2 kg per hour. There was no catch from the area '9'. In the second year all the areas fished excepting '24' and '10', registered moderate to good catch rates ranging between 33 kg from the area '12' and 45 kg per hour of fishing from the area '11' for the catches ranging between 198 kg from the area '25' and 53,010 kg from '11'. The area '24' yielded 216 kg and '10', 4,032 kg for a common catch rate of 16 kg per hour in both the cases. The areas '25', '19', '12' and '11' are rich, '18', '17' and '10' are moderately rich and '24' and '9' are poor in their yields as judged by their catch rates.

In the Veraval region, of the two areas '3' and '2', the former was more productive than the latter. In both the catch and catch rates were better in the first year than in the second. Area '3' had a catch of 9,090 kg for a catch rate of 26 kg per hour in the first year and 6,030 kg for a catch rate of 22 kg per hour in the second year. In '2' the catch of 7,362 kg in the first year had a catch rate of 22 kg per hour and 6,264 kg in the second year had a catch rate of 18 kg per hour. Both the areas in this region should be considered only moderately rich.

The area 'A' in the Porbundar region recorded the maximum catches in both the years, being 39,348 kg in the first year and 15,624 kg in the second. This area ranked first in respect of catch rate which was 33 kg per hour in the first year, but was only third in the second year, with a catch rate of 17 kg per hour of fishing. 'A' in the first year was followed by the areas 'D' with a catch of 4,176 kg and a catch rate of 23 kg per hour, 'E' with a catch of 3,600 kg and a catch rate of 20 kg per hour and 'B' with a catch of 72 kg and a catch rate of 9 kg per hour. In the second year this area 'A' was followed by 'E' with a catch of 6,426 kg and a catch rate of 29 kg per hour, 'D' with a catch of 3,654 kg and a catch rate of 16 kg per hour and 'B' with a catch of 1,188 kg and a catch rate of 21 kg per hour. The four areas 'A', 'B', 'D' and 'E' appear to be moderately rich grounds for _P. heptadactylus_.

In Dwarka region, though the catches of 2,682 kg and 900 kg were the least from area 'L' in the first and the second years, their catch rates of 57 kg and 45 kg per hour respectively were very high. In the first year, the maximum yield of 14,688 kg with a catch rate of 30 kg per hour was from 'M'. Area 'K' yielded a catch of 10,548 kg and showed the highest catch rate of 59 kg per hour and 'N' a catch of 7,812 kg with a lowest catch rate of 29 kg per hour. In the second year when 'L' had the highest catch rate, 'N' recorded the highest catch of 8,778 kg for a catch rate of 24 kg per hour. The minimum catch rate of 15 kg per hour for a catch of 6,516 kg was registered by the area 'K'. 'M' had a catch of 7,416 kg and a catch rate of 26 kg per hour. In this region the areas 'K' and 'L' are rich and 'M' and 'N' moderately rich.

Kutch region too appears to have some rich grounds for this species. The highest catch of 720 kg was from the area 'R' with a catch rate of 35 kg per hour in the second year; the highest catch rate of 41 kg per hour was from 'Q' with a catch of 54 kg in the first year. There was no catch from 'U' and 'X'. The area 'P' fished in the first year alone, had a catch of 36 kg and a catch rate of 27 kg per hour. The area 'V' gave a catch of 630 kg with a catch rate of 30 kg per hour, 'Q' a catch of 612 kg with a catch rate of 22 kg per hour and 'S', 18 kg with a catch rate of 14 kg per hour in the second year. Thus 'Q' proves to be rich, 'P', 'R' and 'V' are moderately rich and 'S', 'U' and 'X' poor.

<u>Seasonal Variations in the Catches</u>

The average monthly catches of *P. heptadactylus* for the 8 years period presented in the Table 39 show that they vary between 1.58% for a catch of 4,103 kg and a catch rate of 10.46 kg per hour in June and 4.41% for a catch of 12,749 kg and a catch rate of 36.77 kg per hour in April. Though the catches were fairly good, the percentages were comparatively low in the monsoon months June to August, being 1.7% for a catch of 4,597 kg and catch rate of 10.27 kg per hour in July and 1.95% for a catch of 6,424 kg and catch rate of 14.44 kg per hour of fishing in August. High percentage catches of 4.02 and 4.12 were seen in March and May

Table 39

Monthly catch in Kg (Kg per hour) and percentage of *P. heptadactylus* in the New India Fisheries bull-trawler landings during 1956-1963.

Month	1956	1957	1958	1959	1960	1961	1962	1963	Average
January	-	396 (0.88) 0.14	13,266 (25.38) 3.74	12,834 (22.91) 4.10	19,296 (40.26) 4.53	16,344 (37.88) 4.26	14,836 (34.78) 3.20	6,642 (19.23) 2.03	11,952 (26.01) 3.29
February	-	2,592 (6.35) 0.92	19,404 (42.34) 6.90	7,776 (15.12) 2.60	17,514 (37.49) 4.01	7,398 (13.55) 1.75	5,778 (13.45) 1.39	8,568 (23.00) 2.36	9,861 (22.98) 2.76
March	-	7,452 (17.17) 2.70	14,688 (27.50) 3.85	11,034 (19.8) 3.78	24,480 (53.10) 5.34	30,384 (65.44) 6.93	7,866 (19.4) 2.00	9,540 (18.96) 2.48	15,063 (31.40) 4.02
April	0	28,890 (60.91) 9.54	8,838 (37.57) 5.10	18,774 (43.32) 5.80	15,030 (35.60) 4.08	17,676 (44.43) 4.57	6,048 (22.6) 2.64	6,732 (19.29) 2.53	12,749 (36.77) 4.41
May	0	19,782 (85.47) 11.78	10,224 (34.63) 5.24	10,116 (33.2) 6.2	13,680 (30.50) 3.82	10,512 (31.31) 3.89	6,606 (17.1) 1.93	36 (2. 73) 0.72	8,870 (27.34) 4.12
June	54 (0.16) 0.02	15,390 (29.56) 5.03	2,592 (13.06) 2.64	4,194 (15.87) 2.8	4,032 (8.27) 1.04	4,500 (9.89) 1.56	144 (0.40) 0.04	1,917 (3.71) 0.59	4,103 (10.46) 1.58
July	5,850 (17.74) 2.34	15,804 (30.71) 5.32	7,308 (14.82) 2.55	1,332 (4.43) 0.88	2,124 (4.00) 0.74	2,934 (6.71) 1.24	414 (0.80) 0.11	1,008 (2.2) 0.33	4,597 (10.27) 1.70
August	5,616 (17.02) 1.67	9,018 (17.60) 2.29	21,600 (44.55) 5.53	6,552 (18.15) 3.19	4,554 (10.38) 1.80	1,908 (3.88) 0.64	1,980 (4. 4) 0.48	162 (0.39) 0.05	6,424 (14.44) 1.95

Contd...

Table 39 contd....

Month	1956	1957	1958	1959	1960	1961	1962	1963	Average
September	2,736 (8.29) 0.88	16,326 (38.91) 6.92	18,936 (95.00) 5.71	8,694 (27.12) 4.7	11,664 (28.25) 3.56	3,546 (7.60) 1.06	1,674 (7.3) 0.84	7,041 (21.55) 2.57	8,827 (23.95) 3.22
October	4,680 (14.41) 1.77	5,904 (13.59) 2.60	14,400 (35.86) 4.14	7,560 (28.90) 4.42	7,478 (24.12) 2.60	3,402 (13.80) 1.16	252 (4.1) 0.28	2,034 (10.80) 1.56	5,714 (20.50) 2.52
November	1,680 (5.08) 0.46	11,664 (23.92) 5.36	16,272 (37.58) 4.78	4,896 (30. 8) 2.60	7,362 (29.47) 2.65	846 (5.32) 0.51	1,296 (6.8) 0.81	- -	6,279 (21.97) 2.59
December	2,142 (5.13) 0.81	14,076 (24.80) 4.66	10,080 (18.55) 2.72	8,388 (31. 6) 3.07	6,246 (13.51) 1.60	4,950 (13.31) 1.15	1,548 (7.34) 0.93	-	6,776 (16.71) 2.16

respectively, the catch rates being 31.40 kg per hour for a catch of 15,063 kg in the former and 27.34 kg per hour for a catch of 8,870 kg in the latter.

In 1956 the fishing operations started in April, but yielded no catch of P.heptadactylus in April and May. July recorded the highest percentage of 2.34 for a catch of 5,850 kg with a catch rate of 17.74 kg per hour. Fairly good catches were obtained in August and October also. In August the catch of 5,616 kg formed 1.67% with a catch rate of 17.02 kg per hour and in October the catch of 4,680 kg formed 1.77% with a catch rate of 14.41 kg per hour. In the rest of the months the catches formed poor percentages in 1956.

In 1957, May recorded the highest of 11.78% for a catch of 19,782 kg and the highest catch rate of 85.47 kg per hour. The highest catch of 28,890 kg was in April forming 9.54% with a catch rate of 60.91 kg per hour. The catches were poor in January and February, being 0.14% for a catch of 396 kg with a catch rate of 0.884 kg per hour in the former and 0.92% for a catch of 2,592 kg with a catch rate of 6.35 kg per hour in the latter. In rest of the months the catch of this species ranged from 2.29% in August to 6.92% in September.

The maximum of 6.90% for a catch of 19,404 kg and a catch rate of 42.34 kg per hour was observed in February during the year 1958. The highest catch rate of 95 kg per hour was obtained in September for a catch of 18,936 kg forming 5.71%

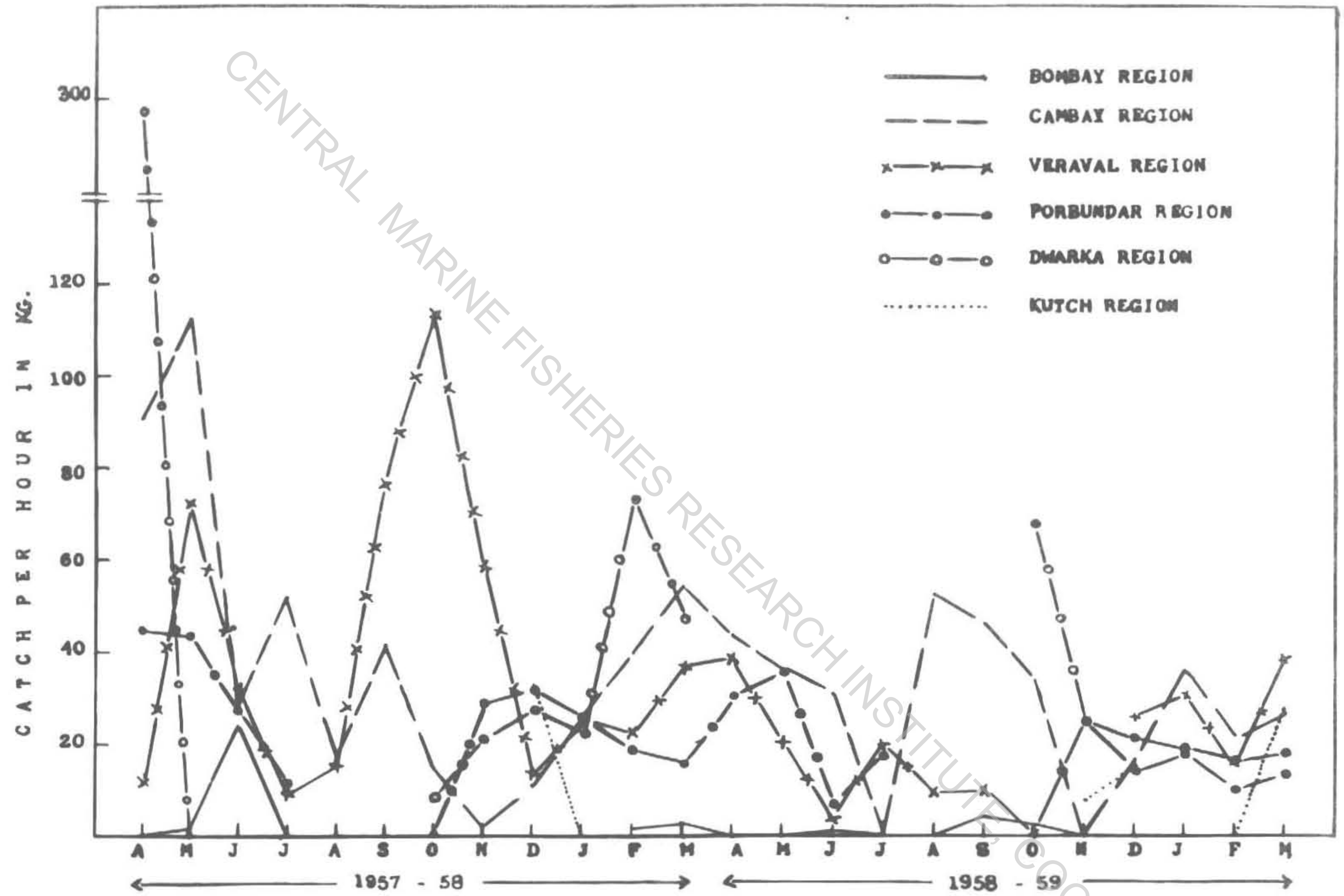
whereas the highest catch of 21,600 kg was seen in August forming 5.53%, giving a catch rate of 44.55 kg per hour. Throughout the year the monthly yields were good, the catch, catch pates and percentage catch being not below 2,592 kg, 13.06 kg per hour and 2.55 respectively.

In 1959 excepting the month of July when the catch of 1,332 kg forming 0.88% had a catch rate of 4.43 kg per hour, all other months registered high catches ranging between 4,194 kg in June and 18,774 kg in April; the catch rates varied from 15.12 kg per hour in February to 43.32 kg per hour in April; and the percentages of this species from 2.60 in February and November to 6.2 in May.

In 1960 the maximum of 5.34% with a catch of 24,480 kg and a catch rate of 53.10 kg per hour was obtained in March. July recorded the lowest catch rate of 4 kg per hour and the lowest percentage of catch of 0.74. Though the yield was fairly good throughout, it was the best during the first five months of the year.

In 1961 the best catch was obtained in March, the catch being 30,384 kg with a catch rate of 65.44 kg per hour and a percentage catch of 6.93. August and November registered very low catches of 1,908 kg with the catch rate of 3.88 kg per hour forming 0.64% in the former and 846 kg with the catch rate of 5.32 kg per hour forming 0.51% in the latter. Excepting in January, April and May, the catches were fair in the rest of the months

46. Monthly catch of *P. heptadactylus* in Kg. per hour of fishing in different regions by the New India Fisheries trawlers during 19[illegible]-195[illegible].


BOMBAY REGION
CAMBAY REGION
VERAVAL REGION
PORBUNDAR REGION
DWARKA REGION
KUTCH REGION
CATCH PER HOUR IN KG.
300
120
100
80
60
40
20
A M J J A S O N D J F M A M J J A S O N D J F M
1957 - 58
1958 - 59

forming about 1 to 2 percent.

The yield of P.heptadactylus in 1962 was much less. The maximum of 14,886 kg forming the highest of 3.20% with the highest catch rate of 34.78 kg was recorded in January. The minimum of 144 kg with the lowest catch rate of 0.40 kg per hour and the lowest percentage of 0.04 was in June. The catch was better in the first five months of the year than in the remaining months when the monthly percentage catch did not go above 1%.

In 1963 excepting the period May to August, the monthly catches were fairly good. In May the effort put was only 13.17 hours and hence, the catch of 36 kg was very poor. The maximum of 2.57% for the catch of 7,041 kg with the highest catch rate of 21.55 kg per hour was obtained, in September. The maximum catch of 9,540 kg was in March for a catch rate of 18,96 kg per hour forming 2.48%. There was no fishery in November and December.

From the above account of the data for nearly 8 years, it is judged that the catches of P.heptadactylus occur throughout the highest and the lowest catches varying in different months in the different years. In general the catches have been found to be slightly poor during June to August in all the years and good in April, May, September and October in most of the years.

Tables 40 and 41 (Fig. 46) show the monthly fluctuations of P.heptadactylus in the six regions for the period April 1957 to March 1959. In the Bombay region during the 5 months out of 9

Table 40

Monthly regional catch in Kg, (Kg per hour) and percentage of *P. heptadactylus* in the New India Fisheries bull-trawler landings during 1957-58.

Month	Bombay	Cambay	Veraval	Porbundar	Dwarka	Kutch
April	0	9,018 (91.20) 16.91	36 (11.68) 3.76	14,112 (44.95) 6.54	5,724 (292.92) 18.22	-
May	36 (1.83) 0.33	16,776 (112.46) 16.60	576 (72.45) 9.12	2,394 (43.79) 4.79	-	-
June	36 (24.00) 8.69	9,558 (28.48) 4.94	5,580 (31.75) 5.14	216 (27.58) 5.16	-	-
July	0	13,158 (52.05) 7.05	1,494 (9.32) 2.11	1,152 (11.70) 3.03	-	-
August	0	8,622 (17.79) 2.33	396 (15.24) 1.74	-	-	-
September	0	15,696 (42.10) 6.87	630 (76.64) 50.00	0	-	-
October	0	3,744 (14.94) 2.89	1,422 (113.76) 53.74	0	738 (8.42) 3.18	-

contd...

Table 40 Contd..

Month	Bombay	Cambay	Veraval	Porbundar	Dwarka	Kutch
November	-	18 (2.51) 1.96	378 (58.91) 11.35	4,428 (29.47) 6.40	6,840 (21.12) 4.74	-
December	-	540 (10.91) 2.34	1,476 (13.67) 2.96	8,640 (31.88) 5.09	3,330 (27.81) 6.54	90 (33.83) 4.74
January	-	846 (26.37) 5.51	1,332 (25.74) 4.86	8,244 (26.00) 3.51	2,844 (23.34) 3.70	-
February	18 (2.08) 0.82	1,926 (40.18) 8.35	1,854 (22.60) 3.04	2,718 (18.65) 15.91	12,888 (74.12) 11.17	-
March	54 (3.28) 0.73	3,186 (54.55) 8.53	1,278 (37.11) 7.48	5,292 (16.36) 15.56	4,878 (48.10) 6.35	-

Table 41

Monthly regional catch in Kg, (Kg per hour) and percentage of *P. heptadactylus* in the New India Fisheries bull-trawlers landings during 1958-59.

Month	Bombay	Cambay	Veraval	Porbundar	Dwarka	Kutch
April	0	5,706 (44.21) 6.11	342 (39.08) 6.34	2,790 (30.36) 3.77	-	-
May	0	5,022 (36.53) 5.93	513 (20.58) 3.00	4,626 (35.80) 5.02	-	-
June	18 (0.97) 0.38	1,854 (31.38) 6.21	216 (4.20) 0.84	504 (7.23) 1.33	-	-
July	0	90 (0.73) 0.25	5,094 (20.51) 3.35	2,124 (17.55) 3.64	-	-
August	0	20,664 (52.88) 6.52	936 (10.08) 1.27	-	-	-
September	54 (4.44) 1.27	18,414 (46.32) 6.01	324 (10.56) 1.60	-	-	-
October	36 (3.27) 0.71	12,060 (34.10) 3.84	0	0	2,304 (68.20) 7.97	-

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Table 41 (contd..)

Month	Bombay	Cambay	Veraval	Porbandar	Dwarka	Kutch
November	0	0	-	2,934 (25.26) 14.04	7,086 (25.31) 3.07	252 (8.02) 1.55
December	-	306 (16.82) 2.86	1,710 (26.16) 4.01	4,140 (14.80) 2.02	3,834 (21.88) 3.49	90 (15.25) 5.08
January	-	3,528 (36.29) 7.22	1,566 (31.10) 5.82	5,904 (18.46) 3.11	1,836 (19.76) 3.73	-
February	0	1,962 (22.35) 3.80	504 (15.74) 3.23	1,728 (10.16) 1.73	3,582 (16.10) 2.63	-
March	0	1,260 (26.62) 5.98	1,026 (38.67) 6.81	2,142 (14.18) 2.55	4,968 (18.38) 3.69	1,638 (27.83) 4.41

fishing months in the first year and during 7 months out of 10 fishing months in the second, the catch of this species was nil. The maximum of 8.69% for a catch of 36 kg and catch rate of 24 kg per hour was obtained in June of the first year. June of the following year recorded 0.38% of this species for a catch of 18 kg and a catch rate of 0.97 kg per hour. In rest of the months, whenever there was catch, it did not go above 54 kg, 4.44 kg per hour and 1.27%.

In the highly exploited Cambay region, the yield was good in almost all the months, with the exception of November of the second year when there was no catch. The highest catch of 16,776 kg with the highest catch rate of 112.46 kg per hour forming the highest of 16.60% was obtained in May of the first year and the highest percentage of 7.22 for a catch of 3,528 kg and a catch rate of 36.29 kg per hour was in January of the second year. The monsoon months of June and July in the first year and June and August in the second also recorded fairly high catches ranging from 1,854 kg to 20,664 kg, with percentages from 4.9 to 7.05 and catch rates from 28.48 to 52.88 kg per hour.

In Veraval the catch was nil in October and there was no fishing in November of the second year. The catch rates and percentage catches were good in all other months, but were very high in May, September to November of the first year and April, January and March of the second year. The monsoon months of June in the first year and July in the second yielded fairly high catches, being 5,580 kg forming 5.14% with a catch rate of

31.75 kg per hour in the former and 5,094 kg forming 3.35% with a catch rate of 20.51 kg per hour in the latter.

In Porbundar, there was no fishing in August of both the years and also in September of the second year. There was no catch in September of the first and October of both the years. The catches were good althrough including in the monsoon months. Amongst the monsoon months, the highest percentage catch of 5.16 and catch rate of 27.58 kg per hour were obtained in June of the first year and the highest catch of 2,124 kg in July of the second year.

In Dwarka region, there was no fishing from May through monsoon months to September in both the years and also in April of the second year. The catch was good in all the fishing months, the highest of 18.22% with the highest catch rate of 292.92 kg per hour for a catch of 5,724 kg being in April of the first year and the lowest of 2.63% with a catch rate of 16.10 kg per hour for a catch of 3,582 kg being in February of the second year.

In the Kutch region the fishing was only in December of the first year, November, December and March of the second year. There was no fishing during monsoon. The catches were fairly good during the months when there was fishing in this region.

It has been stated earlier that the catches of P.heptadactylus are slightly poor during the monsoon months of June to August. The overall low yields are mostly due to the total absence of fishing in Dwarka and Kutch regions in those months (except during 1960 and 1961). In Cambay, Veraval, Porbundar and in the two years 1960 and 1961 of fishing in Dwarka and Kutch, where there was fishing during monsoon months, the catches and catch rates were high.

Depth-wise Distribution

The catch data for the period April 1957 to March 1959 were analysed to know about the depth-wise distribution of *P. heptadactylus*. The fishing operations during this period were carried out at depths between 21 meters and 80 meters. There was only one haul beyond 80 meters (87 meters) in April 1957 in Cambay region and the catch was nil. From the Table 42, it is noticeable that the fishing was concentrated more at the depths 21-50 meters in all the regions throughout in both the years. The higher depths between 51 and 80 meters were fished during the period, in general between April and August in all the regions excepting Dwarka and Kutch.

Bombay region recorded *P. heptadactylus* in both the lower and higher depth ranges. In 21-50 meters depth range the catch varied from 18 kg with the catch rate of 1.87 kg per hour in February 1958 to 108 kg with the catch rate of 6.17 kg per hour in October 1958; in the depth of 51-80 meters the catch ranged between 18 kg with the catch rate of 0.97 kg per hour in June 1958 and 72 kg with the catch rate of 7.42 kg per hour in September

Table 42

Monthly catch of *P. heptadactylus* in Kg. (Kg per hour) in different regions at 21-50 metres and 51-80 metres depth zones during 1957-59

21-50 m.

Regions	M O N T H S																						
	Apr. 1957	May	June	July	Aug	Sept	Oct	Nov	Dec.	Jan 1958	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan 1959	Feb	Mar
Bombay	0	-	-	-	0	0	0	-	-	-	18 1.87	54 3.29	0	-	-	-	-	-	108 6.17	0	-	-	0	0
Cambay	-	-	108 77.14	18 11.25	4,086 16,72	19,692 52.67	3,744 15.01	36 5.07	437 8.65	617 17.47	1,563 34.58	2,250 56.96	-	-	-	-	2,826 21.99	10,494 40.65	9,072 36.63	216 30.00	306 16.81	3,528 38.39	1,962 22.39	1,260 27.09
Veraval	36 12.00	576 72.90	1,960 33.22	198 5.62	270 15.60	630 79.74	1,422 122.58	378 59.06	1,350 12.56	1,697 24.62	1,461 17.00	1,476 41.34	18 14.40	324 26.34	216 14.21	0	216 18.00	468 14.05	0	-	1,944 29.86	1,584 30.57	504 15.75	1,026 38.71
Porbunder	13500 43.99	2,395 46.23	216 33.53	1,062 12.36	-	0	0	5,058 33.58	9,378 32.77	6,575 20.43	1,733 12.34	5,130 16.58	2,790 30.22	6,264 35.11	36 5.29	540 14.71	-	-	0	2,402 29.30	5,316 19.60	5,886 18.59	1,764 10.38	2,142 13.90
Dwarka	5,770 107.24	-	-	-	-	-	738 8.52	7,542 23.53	3,168 26.05	2,813 22.98	10,445 59.61	3,762 36.20	-	-	-	-	-	-	2,304 70.24	14,796 52.06	4,235 23.99	1,626 19.76	3,582 15.96	4,968 15.40
Kutch	-	-	-	-	-	-	-	-	45 17.30	-	-	-	-	-	-	-	-	-	-	324 10.58	90 15.25	-	-	1,638 27.95

51-80 m.

Regions	Apr. 1957	May	June	July	Aug	Sept	Oct	Nov	Dec.	Jan 1958	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan 1959	Feb	Mar
Bombay	-	36 1.75	36 24.00	0	-	-	-	-	-	-	-	-	0	0	18 0.97	0	0	72 7.42	0	-	-	-	-	-
Cambay	5,436 47.57	16,910 112.95	10,759 32.46	16,402 66.08	6,894 29.17	-	-	-	-	-	-	1,116 37.07	5,940 43.26	5,598 37.52	2,268 40.21	270 2.13	17,838 67.33	8,010 57.54	3,744 36.16	-	-	-	-	-
Veraval	-	-	3,665 33.25	1,296 10.42	198 23.29	-	-	-	-	-	-	-	324 48.00	288 23.04	0	5,094 20.99	720 8.92	-	-	-	-	-	-	-
Porbunder	-	18 6.20	0	90 17.64	-	-	-	-	-	-	-	-	-	-	468 7.39	1,638 13.84	-	-	-	-	-	-	-	-

1958. The maximum catch rate of 24 kg per hour for a catch of 36 kg was observed in June 1957 in the depths of 51-80 meters.

In Cambay region the catch rates ranged between 6.07 kg per hour for a catch of 36 kg in November 1957 and 77.14 kg per hour for a catch of 108 kg in June 1957 in depths of 21-50 meters. The highest catch of 19,692 kg with the catch rate of 52.67 kg per hour was in the same depth range during September 1957. In the higher depths of 51-80 meters, the catch rates ranged between 2.13 kg per hour for the lowest catch of 270 kg in July 1958 and 112.95 kg per hour for a catch of 16,910 kg in May 1957; the highest catch of 17,838 kg with a catch rate of 67.33 kg per hour was in August 1958.

In Veraval region the catch ranged between 18 kg with a catch rate of 14.4 kg per hour in April 1958 and 1,960 kg with a catch rate of 33.22 kg per hour in June 1957 whereas the catch rates were between 12 kg per hour for a catch of 36 kg in April 1957 and 79.74 kg per hour for a catch of 630 kg in September 1957 in the depth of 21-50 meters. The catch rates in the higher depths of 51-80 meters ranged between 8.92 kg per hour for a catch of 720 kg in August 1958 and 48.00 kg per hour for a catch of 324 kg in April 1958.

The fishing in the higher depths of 51-80 meters was comparatively less in Porbundar region. The catch rates ranged between 5.29 kg per hour for a catch of 36 kg in June 1958 and 46.23 kg per hour for a catch of 2,395 kg in May 1957 in the depths

Table

Depth-wise distribution of monthly catch in kg

1957 - '58

Month	21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m.
April 1957	-	-	-	4,806 (72.81)	4,860 (111.45)	54 (36.00)
May	-	-	-	3,240 (104.18)	13,484 (115.14)	54 (38.57)
June	-	-	108 (77.14)	1,962 (48.44)	8,712 (29.95)	-
July	-	-	18 (2.06)	3,042 (37.60)	13,230 (82.63)	-
August	-	-	4,086 (16.72)	6,894 (30.09)	144 (22.15)	-
September	306 (102.00)	12,924 (70.04)	6,462 (34.92)	-	-	-
October	126 (11.55)	3,114 (14.40)	504 (22.70)	-	-	-
November	-	36 (8.00)	0	-	-	-
December	-	437 (8.65)	-	-	-	-
January 1958	-	617 (17.47)	-	-	-	-
February	-	959 (32.61)	594 (38.570	-	-	-
March	-	1,440 (54.54)	810 (61.83)	-	1,116 (37.07)	-

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(kg per hour) of *P. heptadactylus* in Cambay Region, 1957-59.

1958 -59

21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m.
-	-	-	576 (36.00)	5,364 (44.22)	-
-	-	-	342 (24.78)	5,256 (38.84)	-
-	-	-	72 (9.60)	1,512 (44.86)	684 (45.00)
-	-	-	36 (0.23)	234 (13.00)	-
-	-	2,826 (21.99)	17,676 (68.08)	162 (30.56)	-
-	1,548 (31.33)	8,946 (42.86)	6,480 (51.75)	1,530 (109.28)	-
450 (44.55)	6,732 (41.04)	2,790 (33.25)	2,898 (37.94)	846 (28.92)	-
-	216 (60.00)	-	-	-	-
90 (20.00)	216 (15.76)	-	-	-	-
-	3,528 (36.37)	-	-	-	-
-	1,962 (22.39)	-	-	-	-
-	1,260 (27.87)	0	-	-	-

of 21-50 meters. The highest catch of 13,500 kg in this depth range was in April 1957 when the catch rate was 43.99 kg per hour. The catch in the depths of 51-80 meters ranged between 18 kg with the lowest catch rate of 6.20 kg per hour in May 1957 and 1,638 kg with the highest catch rate of 18.84 kg per hour in July 1958.

In Dwarka region the fishing was in the depths of 21-50 meters only. The catch rates ranged between 8.52 kg per hour for the lowest catch of 738 kg in October 1957 and 107.24 kg per hour for a catch of 5,770 kg in April 1957. The highest catch of 14,796 kg with a catch rate of 52.06 kg per hour was in November 1958.

In Kutch region, which was the least exploited, in depths of 21-50 meters, the catch rates varied from 17.30 kg per hour for the lowest catch of 45 kg in December 1957 to 27.95 kg per hour for the highest catch of 1,638 kg in March 1959. Fishing was not extended to depths between 51 and 80 meters.

In order to ascertain the density of catch at different depths, the analysis was carried out in detail in the depth zones of 10 meters interval. This study was not extended to Bombay and Kutch regions since the data were insufficient. In Table 43 for Cambay region the catch in the depth beyond 50 meters was good at 61-70 meters, wherein the catch rates ranged between 13 kg per hour for a catch of 234 kg in July 1958 and 115.14 kg per hour for a catch of 18,484 kg in May 1957. In the preceding

Table No.

Depth-wise distribution of monthly catch in Kg (Kg per hou

1957 - '58

Month	21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m.
April 1957	-	36 (12.00)	-	-	-	-
May	-	-	576 (72.90)	-	-	-
June	-	-	1,944 (32.94)	3,582 (39.97)	54 (2.64)	-
July	-	-	198 (5.62)	738 (6.83)	558 (34.23)	-
August	-	-	270 (15.60)	198 (23.29)	-	-
September	-	630 (79.74)	-	-	-	-
October	0	1,422 (194.79)	0	-	-	-
November	-	378 (59.06)	-	-	-	-
December	-	1,350 (12.56)	-	-	-	-
January 1958	-	1,697 (24.62)	-	-	-	-
February	-	995 (15.14)	486 (22.71)	-	-	-
March	-	1,314 (43.94)	162 (27.93)	-	-	-

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of *P. heptadactylus* in Veraval region, 1957 - '59.

1958 - '59					
21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m
-	18 (15.00)	-	234 (45.00)	90 (60.00)	-
-	324 (26.34)	-	288 (23.04)	-	-
-	-	216 (14.21)	0	-	-
-	-	0	1,962 (13.08)	3,132 (33.82)	-
-	-	216 (18.00)	720 (9.00)	-	-
-	0	468 (15.00)	-	-	-
-	0	-	-	-	-
-	-	-	-	-	-
378 (21.72)	1,530 (33.84)	36 (14.40)	-	-	-
-	1,584 (30.57)	-	-	-	-
72 (28.80)	432 (14.64)	-	-	-	-
-	1,026 (38.71)	-	-	-	-

depth range of 51-60 meters it was ranging between 0.33 kg per hour for a catch of 36 kg in July 1958 and 104.18 kg per hour for a catch of 3,240 kg in May 1957. In the higher depths of 71-80 meters fairly good catches with 36 kg to 45 kg per hour were obtained. In the depths below 50 meters fishing was concentrated mostly in 31-40 meters where the catch rates ranged between 8 kg per hour for a catch of 36 kg in November 1957 and 70.04 kg per hour for a catch of 12,924 kg in September 1957. The catch was very good in 41-50 meters, the catch rates varying from 2.06 kg and 77.14 kg per hour in July and June respectively of 1957. The depth of 21-30 meters yielded a fairly good catch. In September 1957 there was a very high catch rate of 102 kg per hour for the catch of 306 kg.

Table 44 for Veraval shows that in the depths beyond 50 meters both in 51-60 meters and 61-70 meters the catches were good. The catch rates in the former ranged between 6.83 kg per hour for a catch of 738 kg in July 1957 and 45.00 kg per hour for a catch of 234 kg in April 1957. In the depths below 50 meters the maximum yield was from 31-40 meters, with catch rates ranging between 12 kg per hour for a catch of 36 kg in April 1957 and 194.79 kg per hour for a catch of 1,422 kg in October 1957. The yields in 21-30 meters and 41-50 meters were moderately good.

Table 45 for Porbundar region shows that there was no fishing beyond 51-60 meters. The catch rates at this depth ranged between 6.2 kg per hour for a catch of 18 kg in May 1957 and 18.84 kg per hour for a catch of 1,638 kg in July 1958. In 41-50

Table

Depth-wise distribution of monthly catch in kg (Kg per ho

1957 - 58

Month	21-30m	31-40m.	41-50m.	51-60m.	61-70m.	71-80m.
April	72 (27.69)	13,230 (44.47)	90 (13.63)	-	-	-
May	-	90 (3.48)	2,286 (87.92)	18 (6.20)	-	-
June	-	54 (27.00)	162 (36.00)	0	-	-
July	-	54 (18.00)	1,008 (12.15)	90 (17.64)	-	-
August	-	-	-	-	-	-
September	-	0	-	-	-	-
October	0	0	-	-	-	-
November	288 (16.08)	4,770 (35.97)	-	-	-	-
December	-	9,378 (32.77)	-	-	-	-
January	-	6,575 (20.43)	-	-	-	-
February	432 (14.44)	1,265 (11.58)	36 (30.00)	-	-	-
March	72 (17.14)	5,058 (16.57)	-	-	-	-

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of P.heptadactylus in Porbundar region, 1957-'59.

1958-59					
21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m.
-	2,718 (30.33)	72 (27.69)	-	-	-
-	3,780 (27.55)	2,484 (60.29)	-	-	-
-	-	36 (5.29)	468 (7.39)	-	-
-	-	540 (14.71)	1,638 (18.84)	-	-
-	-	-	-	-	-
-	-	-	-	-	-
0	0	-	-	-	-
3,240 (29.97)	162 (20.25)	-	-	-	-
3,263 (18.66)	1,674 (18.91)	378 (49.09)	-	-	-
-	5,886 (18.59)	-	-	-	-
72 (9.35)	1,656 (10.20)	-	-	-	-
-	2,142 (13.90)	-	-	-	-

Table

Depth-wise distribution of monthly catch in Kg (Kg per hour)

1957-58

Month	21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m
April	252 (96.92)	4,104 (111.52)	1,368 (95.66)	-	-	-
May	-	-	-	-	-	-
June	-	-	-	-	-	-
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	630 (7.77)	108 (19.63)	-	-	-	-
November	882 (14.00)	6,462 (26.07)	198 (20.62)	-	-	-
December	450 (12.89)	2,718 (31.38)	-	-	-	-
January	2,692 (23.06)	131 (23.39)	-	-	-	-
February	3,929 (38.40)	6,576 (89.13)	-	-	-	-
March	1,080 (19.38)	2,682 (55.75)	-	-	-	-

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of P.heptadactylus in Dwarka region, 1957-59.

1958-59

21-30m.	31-40m.	41-50m.	51-60m.	61-70m.	71-80m.
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
2,070 (79.00)	234 (36.00)	-	-	-	-
8,712 (59.14)	6,012 (45.57)	72 (14.4)	-	-	-
414 (8.24)	5,621 (47.59)	0	-	-	-
18 (3.60)	1,728 (20.25)	90 (36.00)	-	-	-
36 (6.10)	3,474 (16.24)	72 (16 .00)	-	-	-
1,656 (15.66)	3,312 (20.18)	-	-	-	-

meter depth range the yield was good varying between 5.29 kg per hour for a catch of 36 kg in June 1958 and 87.92 kg per hour for a catch of 2,286 kg in May 1957. The yield was moderately good in the lower two depths of 21-30 meters and 31-40 meters with the maximum of 29.97 kg per hour for a catch of 3,240 kg in November 1958 in the former and 44.47 kg per hour for a catch of 13,230 kg in April 1957 in the latter.

In Dwarka region as seen in Table 46 there was no fishing beyond 50 meters. At depths of 31-40 meters the yields were very high with the catch rates ranging between 16.24 kg per hour for a catch of 3,474 kg in February 1959 and 111.52 kg per hour for a catch of 4,104 kg in April 1957. The fishing was comparatively less in depths of 41-50 meters which along with those of 21-30 meters recorded, however, fairly good yields.

From the above it is clear that the yield of *P. heptadactylus* was good in all the depths fished upto 80 meters in Cambay, 70 meters in Veraval, 60 meters in Porbundar and 50 meters in Dwarka. In general, the depth of 31-70 meters appears to be very good for this species. It is also interesting to note that relatively a greater coverage is given for fishing at higher depths in the southern than in the northern regions of Bombay and Saurashtra waters.

Influence of Tides on the Catch of P. heptadactylus

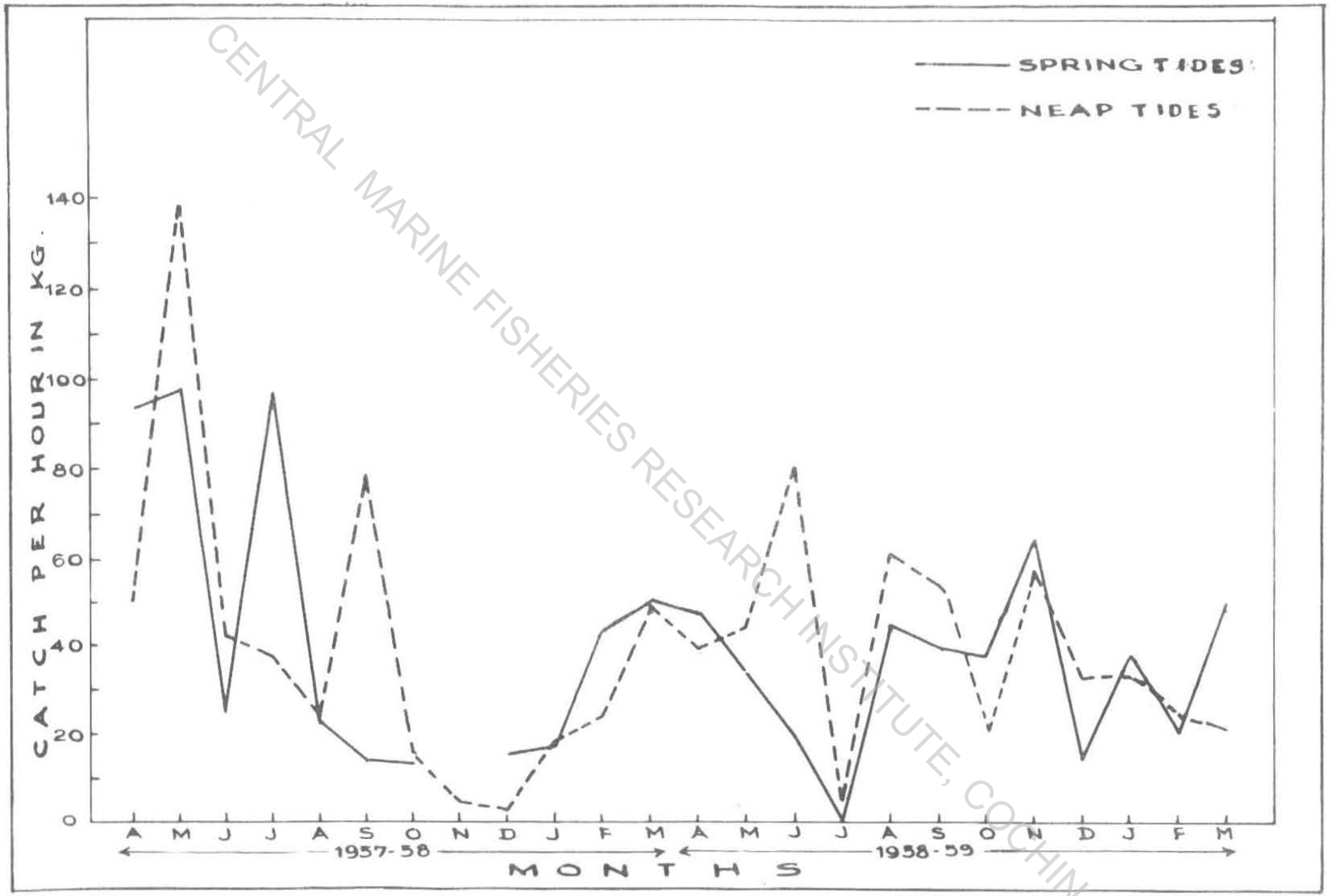
Variations in the catch abundance caused by the spring

Table 47

Monthly Spring tide and Neap tide catch of *P. heptadactylus* in Kg (kg per hour) in Cambay region during 1957-59.

Month	1957-58		1958-59	
	Spring tide	Neap tide	Spring tide	Neap tide
April	8,748 (92.37)	972 (49.59)	3,600 (46.81)	2,340 (38.74)
May	8,892 (95.81)	7,884 (138.80)	2,592 (32.23)	3,006 (43.75)
June	4,266 (24.10)	6,516 (41.84)	666 (18.44)	1,602 (79.30)
July	11,646 (94.83)	4,644 (36.59)	0	270 (5.20)
August	4,608 (22.48)	6,516 (23.69)	7,290 (43.36)	13,374 (59.36)
September	1,998 (13.95)	17,694 (77.09)	6,426 (38.45)	12,078 (52.44)
October	1,332 (13.03)	2,412 (16.38)	6,336 (36.33)	3,780 (20.79)
November	- (	36 (5.07)	144 (62.60)	72 (55.38)
December	369 (15.50)	72 (2.69)	216 (14.02)	90 (32.14)
January	180 (16.66)	441 (18.07)	2,808 (37.14)	720 (33.80)
February	1,098 (43.05)	459 (23.65)	918 (20.40)	1,044 (24.56)
March	1,296 (50.62)	2,070 (46.93)	486 (48.60)	774 (21.26)

47. Monthly spring-tide and neap-tide catch of <u>P. heptadactylus</u> in Kg. per hour of fishing in Cambay region by the New India Fisheries trawlers during 1957-'58.



SPRING TIDES
NEAP TIDES
CATCH PER HOUR IN KG.
0
20
40
60
80
100
120
140
A M J J A S O N D J F M A M J J A S O N D J F M
1957-58
1958-59
MONTHS

and neap tides which in turn are influenced by the variations in the phases of the moon are indicated in the works of Hickling (1946), Rounsefell and Everhart (1953) and Jayaraman et al (loc.cit.) It is clear from these earlier works that the spring and neap tides have a well marked influence on the fishery of certain species of fishes whereas in certain others, it is either nil or very unsteady.

Following the previous workers, the months for the period April 1957 to March 1959 were divided into spring tide and neap tide periods. Each of these periods is about 7-8 days, with either of the two phases of moon (Full or New) in the Centre in the case of spring tides and with either of the remaining two phases of moon (First or Last quarter) in case of neap tides.

The catch in Bombay region and the fishing in Kutch region were so poor that it was not possible to correlate the catches from these regions with the tidal factor.

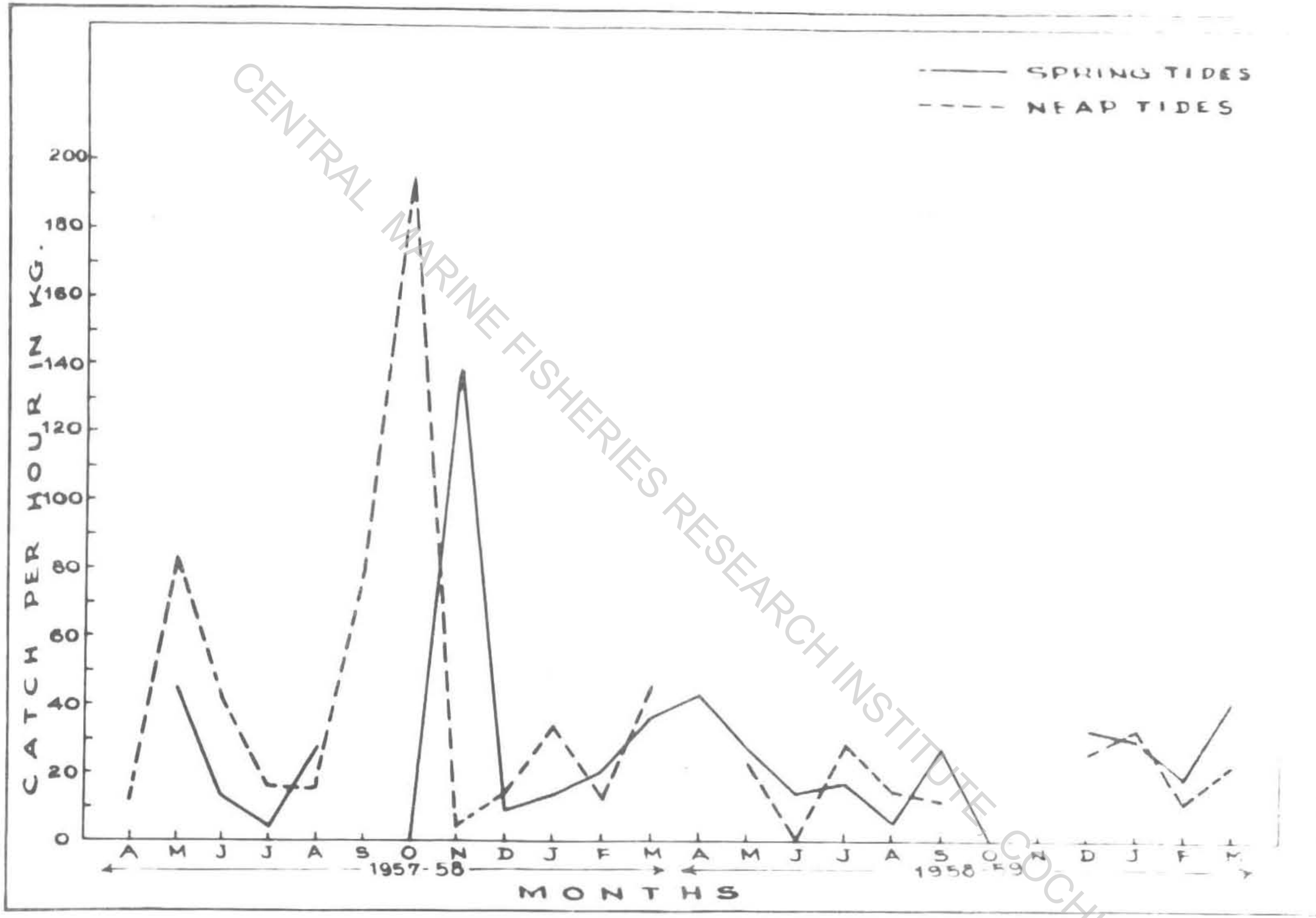
The catch of P.heptadactylus in Cambay region is shown in Table 47 and Fig. 47. Of the 12 months of fishing in each of two years in this region, it was noticed that the neap tide catch was the maximum in 7 months in both the years. The highest catch rate of 138.80 kg per hour for a catch of 7,884 kg was obtained in May 1957 whereas, the lowest of 2.69 kg per hour for a catch of 72 kg was in December 1957. The highest spring tide catch rate of 95.81 kg per hour for a catch of 8,892 kg was also obtained in May 1957 and there was no spring tide catch in July 1958. The variations

Table 48

Monthly Spring tide and Neap tide catch of *P. heptadactylus* in Kg (Kg per hour) in Veraval region during 1957-'59.

Month	1957 - '58		1958 - '59	
	Spring ~~Catch~~ tide	Neap ~~Catch~~ tide	Spring ~~Catch~~ tide	Neap ~~Catch~~ tide
April	-	36 (11.61)	342 (42.75)	-
May	90 (45.00)	486 (82.37)	324 (26.34)	288 (23.04)
June	666 (12.95)	4,914 (41.67)	162 (13.50)	54 (1.39)
July	360 (4.06)	1,134 (15.97)	2,664 (17.02)	2,430 (27.39)
August	216 (26.66)	252 (14.31)	216 (4.81)	720 (15.06)
September	-	630 (79.74)	198 (27.12)	270 (10.38)
October	0	1,422 (194.79)	0	-
November	360 (138.46)	18 (4.86)	-	-
December	144 (8.42)	1,206 (13.35)	1,116 (32.92)	828 (26.53)
January	423 (13.21)	1,260 (34.23)	684 (29.48)	900 (31.46)
February	972 (20.81)	513 (12.69)	198 (9.00)	108 (10.90)
March	648 (35.60)	828 (47.31)	936 (41.78)	90 (22.50)

48. Monthly spring-tide and neap-tide catch of *P. heptadactylus* in kg per hour of fishing in Veraval region by the New India Fisheries trawlers during 1957-'59.



SPRING TIDES
NEAP TIDES
CATCH PER HOUR IN KG.
0
20
40
60
80
100
120
140
160
180
200
A M J J A S O N D J F M A M J J A S O N D J F M
1957-58
1958-59
MONTHS

between the spring and neap tide catches were wide during the five months of April, May, July and September 1957 and also of June 1958.

The tidal influence on the catches was well marked in the Veraval region (Table 48, Fig. 48) during 1957-58 fishing season. Excepting in the three months of August and November 1957 and February 1958 the neap tide catch was predominant throughout. The maximum catch rate of 194.79 kg per hour for a catch of 1,422 kg was obtained in October 1957 when the spring tide catch was nil, in spite of the fact, that the effort put in here was nearly half that during the neap tide period. The second high catch rate of of 82.37 kg per hour for a catch of 486 kg was in May 1957 when the spring tide catch rate w s 45 kg per hour for a catch of 90 kg. The maximum spring tide catch rate of 138.46 kg for a catch of 360 kg was noticed in November 1957 when the corresponding neap tide catch rate was only 4.86 kg per hour and the catch 18 kg though the effort put in was more than that in the first. This well marked variation was not noticed in the following year of 1958-59. Of the 11 months of fishing during this season and October 1958 registering nil catch, the spring tide catch predominated throughout excepting in the three months of July and August 1958 and also January 1959. The spring tide catch rates of April 1958 and March 1959 were more, giving the values of 42.75 kg per hour for a catch of 342 kg and 41.78 kg for a catch of 936 kg respectively. The highest neap tide catch rate of 31.46 kg per hour for a catch of 900 kg was noticed during

Table 49

Monthly Spring tide and Neap tide catch of *P. heptadactylus* in Kg (Kg per hour) in Porbundar region during 1957-'59.

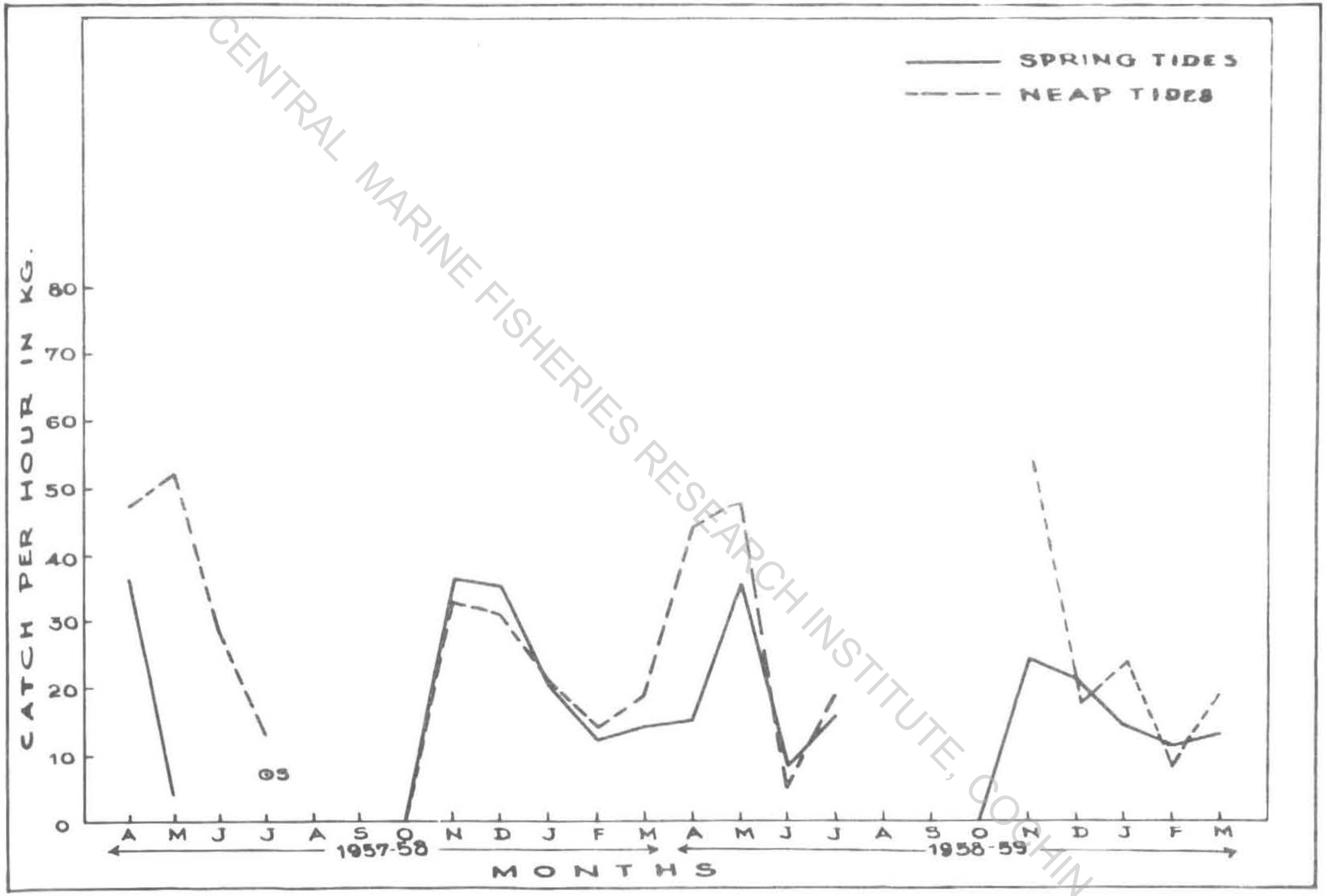
Month	1957 - '58		1958 - '59	
	Spring ~~Catch~~ tide	Neap ~~Catch~~ tide	Spring ~~Catch~~ tide	Neap ~~Catch~~ tide
April	3,330 (36.00)	10,062 (46.95)	684 (15.37)	2,106 (44.15)
May	36 (4.13)	2,358 (51.26)	5,220 (33.41)	1,044 (47.02)
June	-	216 (27.69)	396 (8.16)	108 (5.02)
July	36 (6.54)	1,116 (13.05)	828 (16.62)	1,350 (18.31)
August	-	-	-	-
September	-	0	-	-
October	0	0	0	-
November	2,070 (35.62)	2,988 (32.33)	2,052 (22.57)	1,350 (53.78)
December	4,770 (35.30)	4,608 (30.51)	3,006 (21.33)	2,313 (17.81)
January	4,221 (20.27)	2,358 (20.77)	2,124 (13.55)	3,762 (23.55)
February	1,089 (11.87)	648 (13.30)	1,422 (10.77)	306 (8.31)
March	1,980 (13.73)	3,150 (19.07)	1,710 (12.95)	432 (19.72)

Table 50

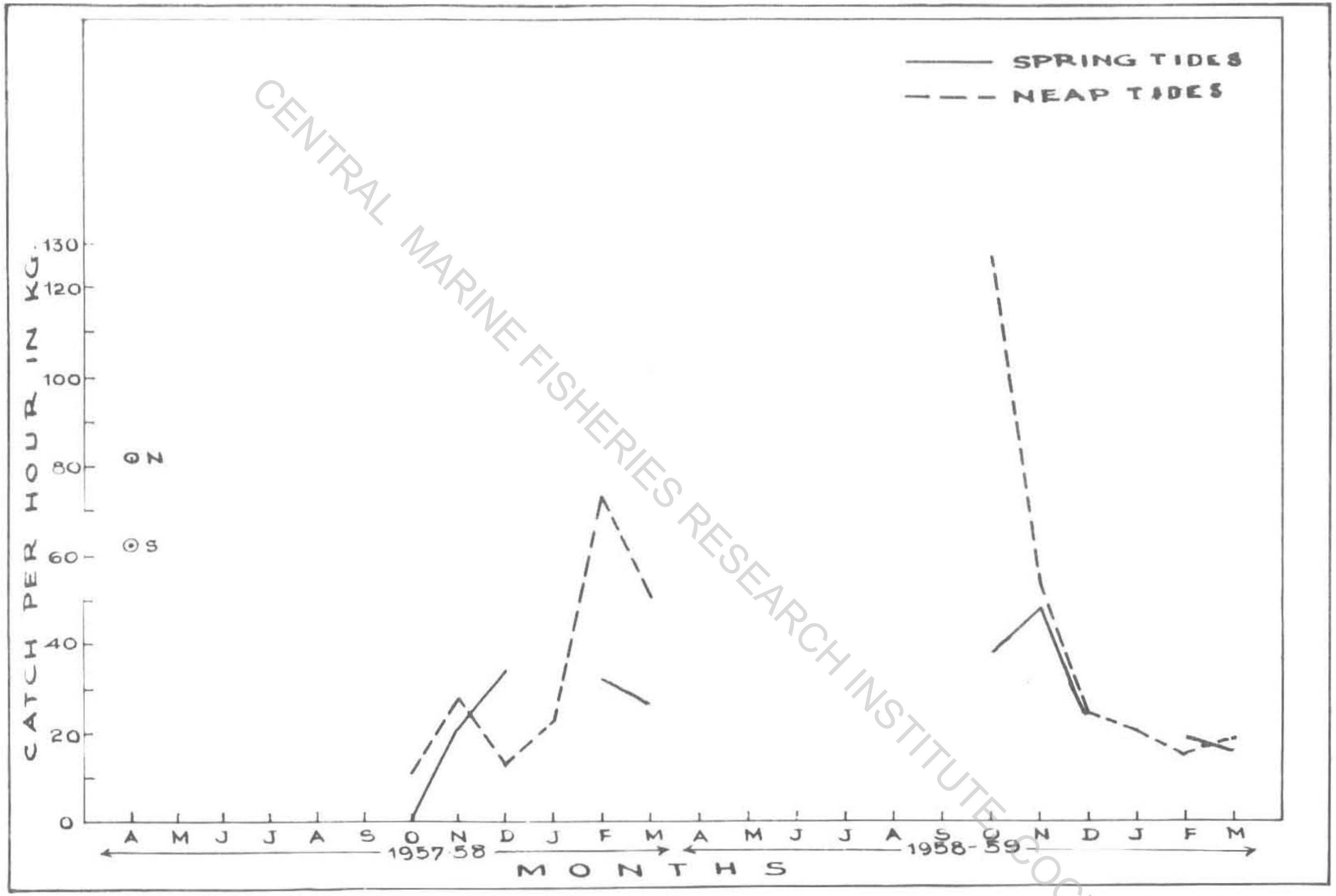
Monthly Spring tide and Neap tide catch of *P. heptadactylus* in Kg (Kg per hour) in Dwarka region during 1957- '59.

Month	1957-58		1958-59	
	Spring ~~Catch~~ tide	Neap ~~Catch~~ tide	Spring ~~Catch~~ tide	Neap ~~Catch~~ tide
April	1,980 (61.68)	1,764 (81.66)	-	-
May	-	-	-	-
June	-	-	-	-
July	-	-	-	-
August	-	-	-	-
September	-	-	-	-
October	36 (1.51)	702 (11.16)	792 (38.07)	1,512 (127.05)
November	3,834 (20.53)	3,708 (27.73)	4,716 (47.73)	10,080 (54.39)
December	2,610 (34.11)	558 (12.40)	1,044 (24.50)	3,195 (23.86)
January	-	2,817 (23.01)	-	1,836 (19.76)
February	1,881 (32.31)	8,568 (73.10)	1,314 (17.82)	2,268 (15.06)
March	1,530 (25.80)	2,232 (50.15)	1,134 (15.68)	3,834 (19.40)

49. Monthly spring-tide and neap-tide catch of _P. heptadactylus_ in Kg per hour of fishing in Porbundar region by the New India Fisheries trawlers during 1957-'59.


SPRING TIDES
NEAP TIDES
CATCH PER HOUR IN KG.
0
10
20
30
40
50
60
70
80
A M J J A S O N D J F M A M J J A S O N D J F M
1957-58
1958-59
MONTHS
G5

50. Monthly spring-tide and neap-tide catch of _P.heptadactylus_ in Kg per hour of fishing in Dwarka region by the New India Fisheries trawlers during 1957-'59.



SPRING TIDES
NEAP TIDES
CATCH PER HOUR IN KG.
130
120
100
80
60
40
20
0
N
S
A M J J A S O N D J F M A M J J A S O N D J F M
1957-58
1958-59
MONTHS

January 1959.

In Porbundar region (Table 49, Fig. 49) excepting in November and December 1957, June 1958 and February 1959, the catch rates at neap tides were higher throughout. However, the differences noticed in the two tidal catch rates during these four months were extremely small, ranging from 2.26 kg in February 1959 and 4.79 kg per hour in December 1957.

In Dwarka region (Table 50, Fig. 50), excepting December of 1957 and 1958 and February of 1959, the neap tide catch predominated all through. The maximum neap tide catch rate of 127.05 kg per hour for a catch of 1,512 kg was noted in the month of October 1958 as against 38.07 kg per hour for a spring tide catch of 792 kg. The second high neap tide catch rate of 81.66 kg per hour for a catch of 1,764 kg was in April 1957 and the lowest of 11.16 kg per hour for a catch of 702 kg was during October 1957. The maximum spring tide catch rate was obtained in April 1957 when it was 61.68 kg per hour for a catch of 1,980 kg and the lowest in October 1957 with 1.51 kg per hour for a catch of 36 kg.

From the records of catch statistics in the two years as detailed above, it is inferred that the landings of P. heptadactylus are influenced to a great extent by the tides, the catches being more towards the neap tides than during spring tides in all the regions.

SUMMARY

The investigations on the biology and fishery of Polynemus heptadactylus, which extend over a period of three years from 1956 to 1959 have been based on the samples of the material collected from the landings by the 'Dol' nets at Versova and the otter trawls and bull-trawls at Sassoon Docks, Bombay.

The family Polynemidae belonging to the order Persesoces, Percomorphi or Mugiloidea, can be differentiated from the three other families, viz., Sphyraenidae, Mugilidae and Atherinidae under the same order, by the presence of a varying number of free pectoral filaments at the lower part of the pectoral fins. P.heptadactylus has seven free pectoral filaments reaching the ventral fin or extending even beyond. A well-developed shoulder bloch and the presence of an air bladder are recorded for the first time in this species.

Its distribution seems to be restricted to the Indo-Australian waters. Though tropical in habitat, it is not found in the African or Philippine waters. In the Indian waters it occurs both in the east and west coasts. On the north western part of India it supports a fishery of local importance.

The food analysis was carried out by points method. Empty stomachs appeared in very high percentages in both the juveniles and adults all through the year. They showed no

relationship with any seasonal changes in the environmental factors.

P.heptadactylus is a carnivorous fish. Its food composition varied widely, crustaceans ranking first followed by pisces, polychaetes, molluscs and echinoderms. The planktonic forms dominated by copepods were observed in the food of juveniles alone. In the food of juveniles crabs, molluscs and echinoderms were absent but present in adults. Amongst the crustaceans, *Acetes indicus* and *Squilla* spp. dominated in juveniles whereas in adults penaeid and other prawns, followed by *Squilla* spp. Amongst fish food, *Bregmaceros mcClellandi* ranked high in both the juveniles and adults. The differences in the food composition of juveniles and adults indicate that the former prefer inhabiting surface waters and the latter the deeper regions. The feeding intensity varied greatly in both the juveniles and adults, but showed no relation to the breeding behaviour of the fish.

The age and growth of *P.heptadactylus* was determined by the study of growth checks on hard parts like otoliths and scales and of length frequency distribution. Furcal length was adopted throughout the course of studies. The scales are ctenoid. They were chosen for age determination study from the lateral body-wall, beneath the distal end of the pectoral fin.

The relationship between otolith-length and fish-length is expressed by the equation:

$$y = -0.07 + 21.05x \qquad \text{where } y = \text{fish-length and } x = \text{otolith-length}$$

The linear growth of otolith was found to be disproportionately faster till the fish reached 80 mm in length. Later, the growth of fish and otolith were in direct proportion till 160 mm of fish-length after which, the growth again became disproportionate because the deposition of calcium carbonate was towards the thickness of the otolith rather than in its length.

The relation between the scale-length and fish-length has been expressed by the equation:

$$y = 9.87 + 22.97\,x \qquad \text{where } y = \text{fish-length and } x = \text{scale-length}$$

The scales on the lateral body-wall lying beneath the distal end of the pectoral fin appear to develop when the fish is about 10 mm in furcal length.

The first ring on the otolith appearing when the fish is about 26 mm in furcal length, is considered as larval ring. There is no ring corresponding to this on the scale. The subsequent second, third, fourth and fifth rings on the otoliths and the first, second, third and fourth rings on the scales seem to appear at fish-lengths of 83 mm, 128 mm, 158 mm and 188 mm respectively.

The number of rings on otoliths and scales was found to be high during the periods September-November and March-May. The causes of the formation of these growth checks in

P.heptadactylus are not known, but they appear to be annual in nature. The regularity in which the rings on the otoliths and scales appeared at definite length intervals proved that these rings are valid in age determination.

The study of the growth checks on the otoliths and scales and also the length frequency distribution showed that the fish enters ninth year at a length of 273 mm with the annual growth rate of about 83 mm in the first year, 45 mm in the second, 30 mm each in the third and fourth years, 24 mm each in the fifth and sixth and 18 mm each in the seventh and eighth years of its life. There was no variation in the rate of growth of this fish in different months of a year. Rates of growth in males and females were found to be equal in the same age-groups. However, the males in the fifth year were rare and totally absent in the higher age-groups, the largest male recorded being 210 mm as against 273 mm in furcal length of a female.

Both 'Dol' and trawl landings revealed two recruitments in a year, one in about May, the premonsoon brood, and the other in about November, the postmonsoon brood. In the 'Dol' samples examined the premonsoon batches recruited in the month May and the postmonsoon batches in the month November of the successive years from 1954 to 1958, were noticed. Likewise, in the trawler samples the premonsoon batches of May recruited in the successive years from 1950 to 1957 with the exception of 1955 and the postmonsoon batches of November from 1948 to 1956 with the exception of 1954, were also observed.

By the application of von Bertalanffy's growth equation, viz.,

$$L_t = L_\infty \left(1 - e^{-k\,(t-t_0)} \right)$$

to the age-length data it has been found arithematically that L_∞ = 368 mm, k = 0.1570 and t_0 = -0.59

The growth parameters obtained graphically by Walford's method are L_∞ = 368 mm, k = 0.1543 and t_0 = -0.63; there is hardly any difference between these values and those obtained by the application of Von Bertalanffy's equation.

Thus the growth equations by these two methods have been expressed in case of P. heptadactylus as follows:

$$L_t = 368 \left(1 - e^{-0.1570\,(t-(-0.59))} \right)$$

and

$$L_t = 368 \left(1 - e^{-0.1543\,(t-(-0.63))} \right)$$

The 'Dol' samples were dominated by the first year-groups, followed in fair numbers by second and third year-groups and in stray numbers by the fourth year groups. In the otter trawl samples also the first year-group dominated, but the second year-group was represented better than in 'Dol' samples and the other age-groups occurred in stray numbers only.

The number of fish and their weights calculated for the bull-trawler landings showed the total absence of first year-group, poor representation of second year-group, well representation of third and fourth year-groups and poor contribution by fifth year-group and above.

Maturity cycle in the females has been described. Based on the external morphological characters of the ovaries and microscopic details of the ova along with their diameter measurements, a maturity key has been prepared. The mature ripe transparent ova in this species measure from 0.64 mm to 1.04 mm in diameter; the number of oil globules in them vary from one to many and when only one, its diameter ranges from 0.2 mm to 0.3 mm.

Most of the maturity stages appeared throughout the year in the catches of the inshore and offshore waters with immature stages in very high percentages in the former and the advanced and spent stages in a higher proportion in the latter. Spawning appears to be throughout the year with two peak periods in March-June and August-November in both the inshore and offshore waters. Spawning intensity seems to be greater in the latter. The fish are noticed to spend their juvenile stage in the inshore region.

Almost 50% of females are found to attain their first sexual maturity at 133 mm when they complete their second year of life and enter the third year.

Females dominated males in almost all length groups. Males were totally absent beyond the length group of 203 mm.

Sex-composition of *P. heptadactylus* in the inshore catch showed that females predominated males throughout the year. In the offshore catch in most of the months the females predominated, but in May, June and November the males exceeded the females in number. Only once in June 1958, the two sexes appeared in 1 : 1 ratio in the offshore catch.

Spawning in *P. heptadactylus* is prolonged and the liberation of the ova is in batches. When all the individuals with slight diversity in their spawning periods are considered as a whole, the prolonged spawning appears to extend over the entire year and this answers for the appearance of all the maturity stages throughout the year. The two peak spawning periods of March-June and August-November and the two recruitments noticed in a year indicate that each individual member spawns twice a year with an interval of six months.

Fecundity study showed that the estimated number of ova in different fishes of the same length varied greatly, because of the fact that the ova are shed in batches. Since the knowledge of the number on batches and the time interval between them is lacking it is not possible to estimate correctly the number of ova destined to be spawned in a year.

Studies on the 'Condition' factor have shown that the female *P. heptadactylus* attains its first sexual maturity when it is 133 mm in length and this agrees with the actual observations of samples for size at sexual maturity. The males are found to attain the first sexual maturity at 128 mm when they have completed their second year of life.

The length-weight relationship can be expressed by the formula $W = aL^b$ for male P. heptadactylus as

$$W = 0.00001627\ L^{3.0072}$$

or

$$\log W = -4.7887 + 3.0072 \log L$$

and for females as

$$W = 0.000009933\ L^{3.1048}$$

or

$$\log W = -5.0029 + 3.1048 \log L$$

The increase in weight for males and females at different lengths is almost the same and the differences noticed are negligible. The annual increase in weight in the successive age-groups is regular excepting in the seventh and eighth years when the increase is more or less constant.

Hermaphrodite individuals are commonly met with in P. heptadactylus. In the ovotestes the much narrower testicular parts face each other on their inner surfaces and the larger ovarian portions lie to the exterior.

The regular appearance of hermaphrodites in high percentages in the catch throughout the year suggests that this phenomenon is normal and not teratological. The simultaneous development and also the liberation of both the sex elements indicate that this species is a synchronous hermaphrodite; and instances of hermaphrodites surpassing very often even the males in number are suggestive of their being functional. There is a probability of self-fertilisation in this species because both the ovarian and testicular parts in an ovotestis become spent at the same time. Probably there is no sex reversal in *P. heptadactylus*, because hermaphrodites appear from the smallest size when the sexes can be differentiated till the largest size along with the unisexual males and females. In the sex reversal amongst fishes, generally, it is noticed that upto a certain length or age an individual functions as one sex and thereafter changes to opposite sex.

Hermaphrodites resemble unisexual males in their close relative proportions in the samples and the maximum size to which they grow. They are often mistaken to be females due to the development to a greater extent of the ovarian part and also in having similar maturity stages of the ova.

In an ovotestes the cortical and medullary portions cannot be differentiated; the development of the sex elements appears to be from the somatic substratum.

P. heptadactylus grows to about 273 mm in furcal length and is landed locally by the 'Dol' or bag nets and also by otter and bull-trawls from the Bombay and Saurashtra waters. Description of the gears, vessels, fishing grounds and particulars of catch analysis are given detail.

The percentages of hauls with P.heptadactylus and the total effort in hours expended to obtain catches, roughly indicated the relative region-wise abundance of the species.

The catch analysis for the period of 8 years from April 1956 to October 1963 showed a decline in the catch in different regions in recent years; however, an improvement in the catch was noticed in 1963. The regions Cambay, Dwarka and Kutch have rich, Veraval and Porbundar moderately rich and Bombay poor grounds for this fish. Further analysis of the catch has helped in locating certain rich areas in the different regions.

No marked seasonal variation in the catch of P.heptadactylus was noticed. Both high and low yields and high and low catch rates appeared in all the months in a year.

The fishing was carried out between the depth-zone of 21-80 meters. The catch analysis for the period of two years from April 1957 to March 1959 showed that the higher depths between 51 and 80 meters were fished during the period April to August whereas the depths below 50 meters were fished althrough. Though the range of depths fished differed in different regions, it is observed that in general, the yields are better in the depth-zones between 31-70 meters.

The catch of P.heptadactylus is found to be influenced by the tidal factors, the catches in general, being higher during the neap tides in different regions than during spring tides.

Acknowledgements

It gives me great pleasure to express my deep sense of gratitude to Dr. D.V.Bal, M.Sc., Ph.D. (L'Pool), F.A.Sc., F.Z.S.I., former Director, Institute of Science, Bombay, for his guidance and encouragement during the course of this investigation.

I am indebted to Dr. P.V.Rangnekar, Prof. of Zoology, and Dr. (Mrs.) K. Sohonie, Ph. D. (Cantab.), Director, Institute of Science, Bombay for the facilities afforded for carrying out the investigations at the Institute.

I take this opportunity to thank Dr. S. Jones, D.Sc., F.N.G.S., F.A.Sc., F.Z.S.I., Director, Central Marine Fisheries Research Institute, Mandapam Camp for kindly allowing me to register for the Ph.D. degree.

I am thankful to Shri K.Virabhadra Rao and Shri L.B.Pradhan of the Central Marine Fisheries Research Institute for their valuable suggestions during the course of this investigation.

My thanks are also due to Shri V.N.Kagwade of the Atomic Energy Establishment, Trombay and to Shri K.Srinivasa Rao of the Central Marine Fisheries Research Substation, Bombay for the verification of the results of the statistical analysis attempted by me and incorporated in the thesis.

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THE AIR-BLADDER AND ITS RELATION WITH THE AUDITORY ORGAN IN HILSA TOLI (CUV. & VAL.)

By

KUM. P. D. NAYAK AND D. V. BAL

(Zoology Department, The Institute of Science, Bombay)

CONTENTS

INTRODUCTION

The teleostean air-bladder, generally regarded as being homologous with the lung of higher vertebrates, has attracted attention of many biologists owing to its diversity of form and function. It is a baglike structure, occurring between the vertebral column and the visceral organs. In some fishes the bladder is totally absent.

In the Physostomous fishes the air-bladder communicates with the anterior part of the alimentary canal by means of a pneumatic duct, while in the Physoclistous fishes the pneumatic duct is either closed or altogether absent.

In a few Physostomous fishes like *Ilisha filigera, I. elongata, Opisthopterus tardoore* and *Clupea harengus* the bladder also communicates with the exterior by means of a ventral appendage arising from its postrior end and opening to the outside by the side of the genital aperture (Starks 1911). In the Horse-Mackeral (*Caranx trachurus*), a Physoclistous fish, there is no pneumatic duct, instead the air-bladder sends a special duct anteriorly, opening into the right branchial cavity. The origin and the morphological nature of both these secondarily formed ducts has not been yet ascertained.

Various functions have been attributed to the air-bladder, the first and the widely accepted one being the hydrostatic function. The bladder is also said to help in respiration, resonation and sound production.

In many fishes the bladder is connected with the internal ear. This connection between the two organs is brought about in three different ways.

(1) In *Megalops* (de Beaufort* 1909), Notopteridæ (Bridge 1900), Sparidæ and others a precoelomic diverticulum from the anterior end of the air-bladder is apposed to a fibrous membrane, covering a fontanelle in the outer wall of the auditory capsule, the inner wall of the fibrous membrane being close to the utriculus.

(2) In the Ostariophysi, the connection between the air-bladder and the internal ear is brought about through the chain of ossicles known as Weberian Ossicles, situated on each side behind the posterior region of the skull.

(3) The third or the Clupeoid type of ear-swim-bladder relationship between the air-bladder and the membranous labyrinth was first brought to light by Weber* in 1820, since when a great controversy has raged about it. According to Weber a diverticulum from the utriculus unites with an air-vesicle from the precoelomic diverticulum which starts from the antrior end of the air-bladder. Many workers like Breschet* (1839), Hasse* (1873), de Beaufort* (1909) supported Weber in this respect.

The present work on *Hilsa toli*, a Clupeoid fish, was therefore undertaken with a view to studying these controversial points. The work necessitates the study of the following parts :—

Air-bladder

Hilsa toli which belongs to the group of Physostomous Clupeoid fishes, has a simple, single chambered, fusiform and membranous air-bladder (Fig. 1, AB) communicating with the stomach by a short pneumatic duct. It is placed at an acute angle with the vertebral column and is separated from the coelom by a black pigmented peritoneal membrane (PM). It is said to be simple because there is no intercalation of the arterial and venous capillaries in association with the inner glandular epithelium of the air-bladder, thus giving rise to retia mirabilia. Moreover, the postero-dorsal wall of the bladder is not modified into a thin-walled highly vascular area, called oval.

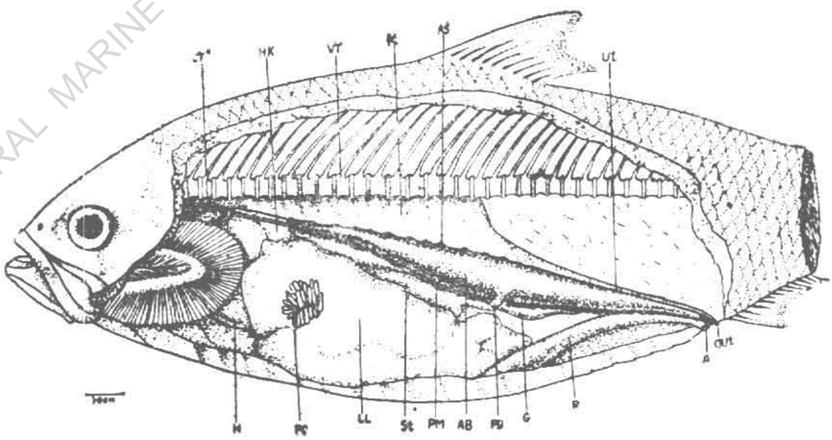
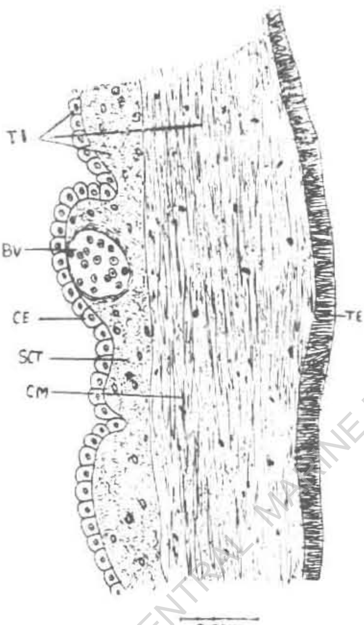


Fig. 1.—Air-bladder and its relation with the general Viscera in *Hilsa toli*.
A Anus ; AB air-bladder ; As aponeurotic sheath ; CT″ bifurcated cartilagenous tube ; G Gonad ; H heart ; HK head kidney ; K Kidney ; LL Liver lobe ; OUt opening of ureter ; PC pyloric cæcæ ; PD pneumatic duct ; PM peritoneal membrane ; R rectum ; ST stomach ; Ut ureter ; VT vertebral column.

Microscopic structure of the air-bladder :—The air-bladder (Figs. 2 and 3) consists of two main layers, the tunica externa (TE) and the tunica interna (TI). Compared with that of other teleosts, the tunica externa is very thin and consists of radially arranged slightly loose fibrous connective tissue. Internal to this, is the thick layer of tunica interna differentiated into three parts : (1) Epithelium lining the lumen of the bladder, (2) Connective tissue and (3) Muscular layer. The epithelium consists of cuboidal cells (CE), the nuclei of which are large, vesicular and located in the centre of the cells. Next to this is the spongy connective tissue (SCT), containing a number of nuclei. Encircling this is a broad layer of circular muscles (CM). According to Tracy (1920), in the case of *Clupea* there is a submucosal layer of loose connective tissue in between the tunica externa and the tunica interna. Instead there is a loose spongy connective tissue in between the muscular layer and the inner epithelial layer of the tunica interna in *Hilsa toli*.



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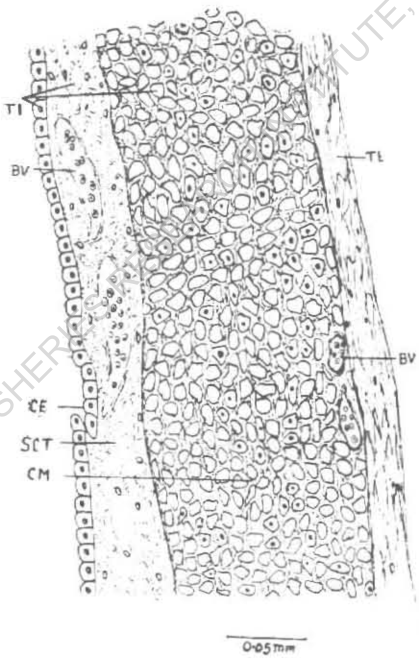

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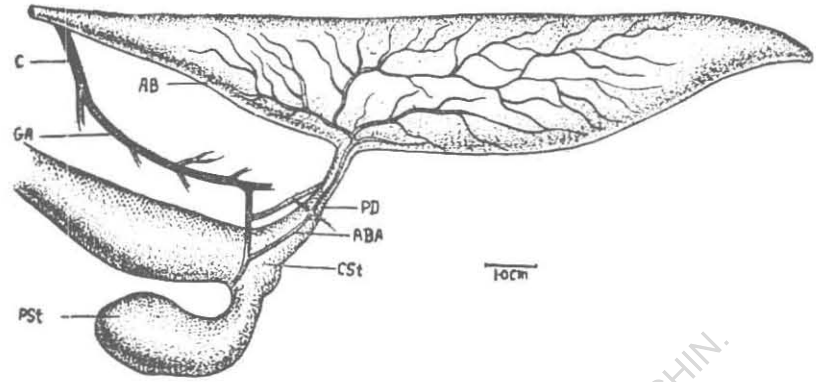
FIG. 2.—Transverse section of the air-bladder of *Hilsa toli*.
FIG. 3.—Longitudinal section of the air-bladder of *Hilsa toli*.

BV blood vessels ; CE cuboidal epithelium ; CM circular muscle ; SCT spongy connective tissue ; TE tunica externa ; TI tunica interna.

The relation of the air-bladder with the general viscera :—The air-bladder lies ventral to the kidney (Fig. 1, k). The narrow gap between the two is filled by a strong aponeurotic sheath (AS) covering the intercostal spaces. In the pericardial region, the narrow end of the bladder is covered on either side by the head kidney (HK) and here the aponeurotic tissue forms a protective and supporting tube around the delicate anterior part of the bladder. This tube comes in contact with an anterior



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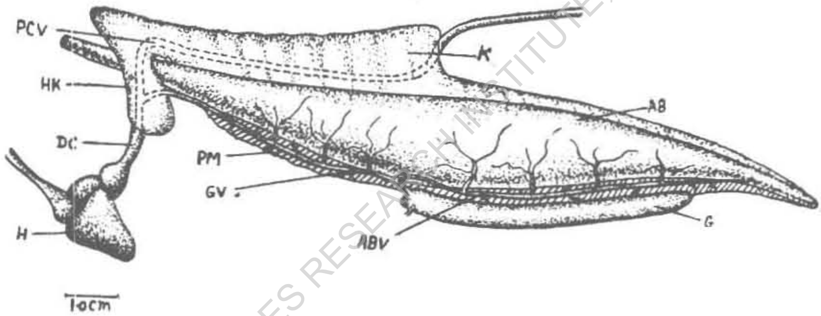

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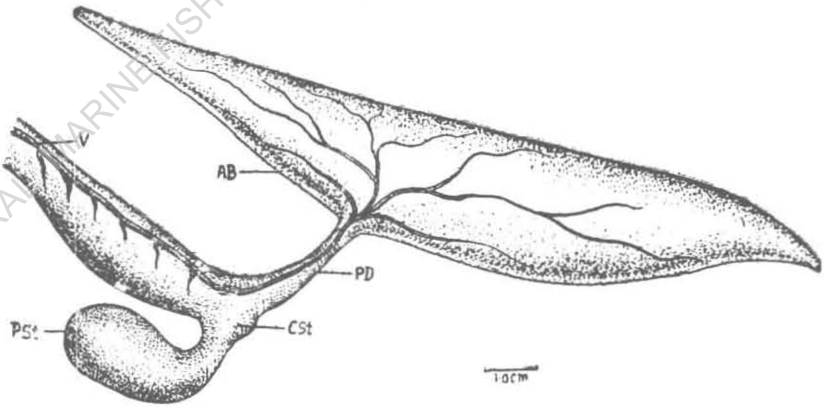

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FIG. 4—Arterial supply of the air-bladder of *Hilsa toli*.
FIG. 5—Venous supply of the air-bladder of *Hilsa toli*.
FIG. 6.—Nervous supply of the air-bladder of *Hilsa toli*.
AB air-bladder ; ABA artery for the air-bladder ; ABV vein from the air-bladder ; C cœliaco-mesenteric artery ; CSt cardiac stomach ; DC ductus cuvieri ; G gonad GA gastric artery ; GV gonadial vein ; H heart ; HK head kidney ; K kidney ; PCV posterior cardinal vein ; PD pneumatic duct ; PM peritoneal membrane ; PSt pyloric stomach ; V visceralis nerve.

cartilagenous tube (Tracy 1920) which at its origin bifurcates into two tubes (Fig. 20, CT[1]). The ventral side of the bladder is in contact with the liver, stomach, pyloric cæcæ, gonads etc.

The Blood and Nervous Supply :—The blood supply (Fig. 4) to the air-bladder is through the gastric artery (GA), arising from the coeliaco-mesenteric artery (C). It gives rise to a prominent transverse artery crossing the posterior part of the cardiac stomach and supplying the bladder through two branches (ABA). Each of these runs on either side of the pneumatic duct and enters the wall of the bladder to form a complete network of blood capillaries. The posterior part of the air bladder is drained (Fig. 5) by a number of small vennules, opening into two small thin veins (ABV). Each of them proceeds anteriorly and joins the gonadial vein (GV), coming out from the anterior end of the gonad. Vennules from the anterior part of the bladder open directly into the gonadial veins. Anteriorly each gonadial vein joins the post cardinal, terminating into the ductus *cuvieri* of the corresponding side. The nervous supply (Fig. 6) of the air-bladder is through the visceralis (V) branch of the vagus nerve.

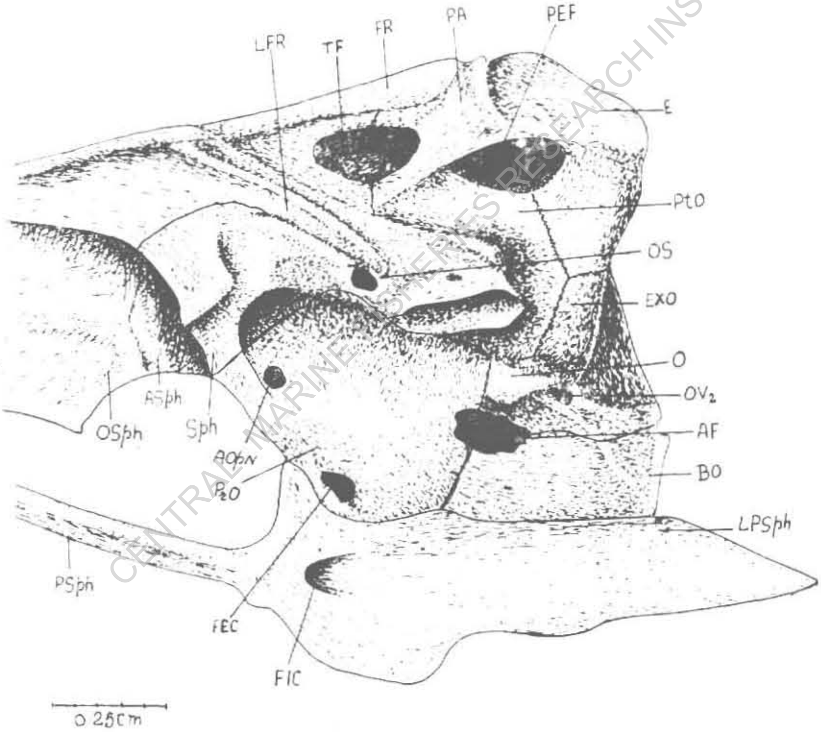
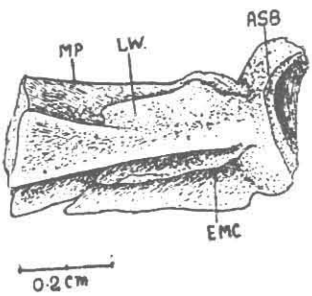


FIG. 7.—Lateral view of the cranium of *Hilsa toli*.
AF auditory fenestra ; AOPN aperture for opercular nerve : ASph alisphenoid ; BO basioccipital ; E epiotic ; EXO exoccipital ; FEC foramen for external carotid artery ; FIC foramen for internal carotid artery ; FR frontal ; LFR lateral wing of frontal. LPSph lateral wing of parasphenoid ; O opisthotic ; OS opening of sense organs ; OSph orbitosphenoid ; OV_2 opening of the Vagus on the outer side ; PRO pro-otic ; PtO pterotic ; PA parietal ; PEF pre-epiotic fossa ; PSph parasphenoid ; Sph sphenotic ; TF temporal foramen.



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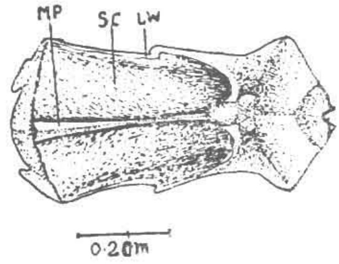

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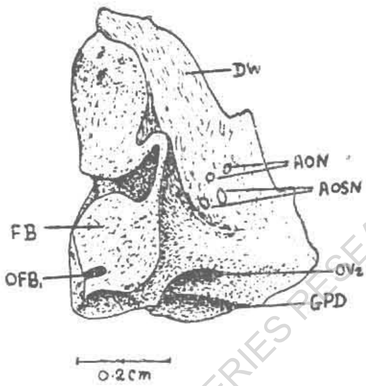

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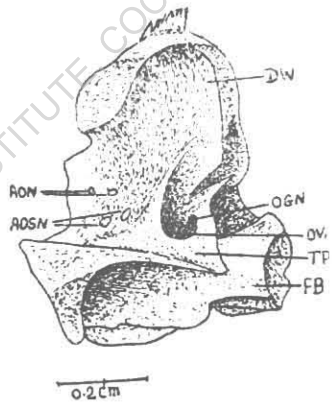

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FIG. 8.—External view of the basioccipital of *Hilsa toli.*

FIG. 9.—Cerebral view of the basioccipital of *Hilsa toli.*

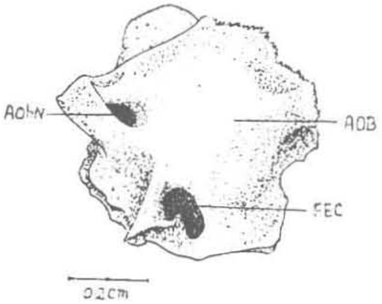
FIG. 10.—External view of the exoccipital of *Hilsa toli.*

FIG. 11.—Cerebral view of the exoccipital of *Hilsa toli.*

AON aperture for occipital nerves ; AOSN apertures for occipito-spinal nerves ; ASB articulating surface of basioccipital ; DW dorsal wing of exoccipital ; EMC eye-muscle canal ; FB fusiform bulla ; GPD groove for the precœlomic diverticulum ; LW lateral wing of basioccipital ; MP median partition ; OFB_1 opening of the fusiform bulla on the inner side ; OGN opening of the Glossopharyngeal nerve ; OV_1 opening of the Vagus on the inner side ; OV_2 opening of the Vagus on the outer side. SC saccular cavity ; TP triangular plate.

THE AUDITORY AND OCCIPITAL REGIONS OF THE SKULL

Basioccipital :—This single bone (Figs. 7 (BO) (*See page 57*), 8 and 9) occupies the postero-ventral part of the cranium and dorsally bears two concavities separated by a median longitudinal partition (MP.) These are known as lateral saccular cavities (SC) and are deepened by the wing like lateral projections (LW) of the bone. Each of them lodges the sacculus of the membranous labyrinth of each side.



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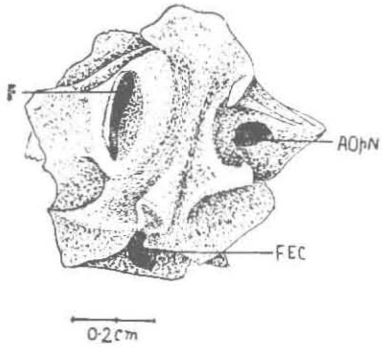

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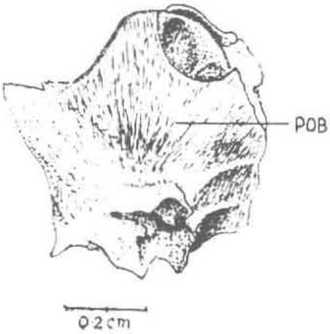

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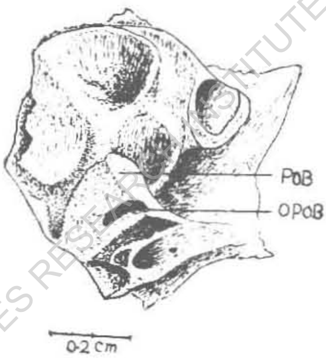

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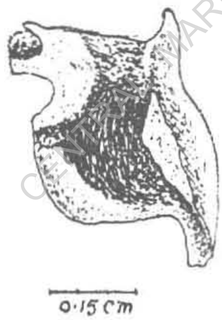

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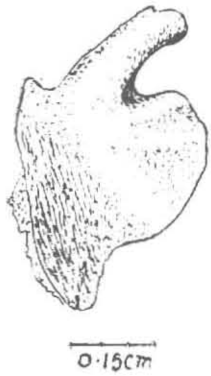

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FIG. 12—External view of the pro-otic of *Hilsa toli*.
FIG. 13—Cerebral view of the pro-otic of *Hilsa toli*.
FIG. 14.—External view of the pterotic of *Hilsa toli*.
FIG. 15.—Cerebral view of the pterotic of *Hilsa toli*.
AOB anterior osseous bulla ; AOpN aperture for opercular nerve ; F fenestra ; FEC foramen for external carotid artery ; OPOB opening of the posterior osseous bulla ; POB posterior osseous bulla.
FIG. 16.—External view of the epiotic of *Hilsa toli*.
FIG. 17.—Cerebral view of the epiotic of *Hilsa toli*.

Exoccipitals :—The paired exoccipitals are (Figs. 10 and 11), situated on the postero-lateral sides of the cranium. The inner surface of the wing like upper part of each bone (DW) which articulates with the supra-occipital and epiotic bones is provided with a depression for lodging the ampulla of the posterior vertical semicircular canal. Laterally, the lower side of the exoccipital is provided with a narrow groove (GPD), forming a path for the air duct or the precoelomic diverticulum from the anterior end of the air-bladder. At the anterior end of this groove, there is a minute aperture for the entrance of the precoelomic diverticulum into the exoccipital. This pin-point aperture opens into the fusiform bulla (FB), found in the anterior region of the lower part of the exoccipital. Anteriorly, the bulla bears an aperture (OFB_1) through which the precoelomic diverticulum emerges out.

Pro-otics :—Each of the pro-otics (Figs. 12 and 13), placed antero-laterally, is flat and disc like, when viewed externally. Its central part is excavated from inside to form an osseous capsule, a characteristic feature of this bone. This capsule is known as the anterior osseous bulla (AOB) or the pro-otic bulla which communicates with the fusiform bulla of the exoccipital through a perforation on the posterior side of the bone. On its cerebral surface is seen an oval fenestra (F), forming an outlet for the anterior osseous bulla. This bulla is divided internally into an upper and lower compartment by an elastic fibrous membrane.

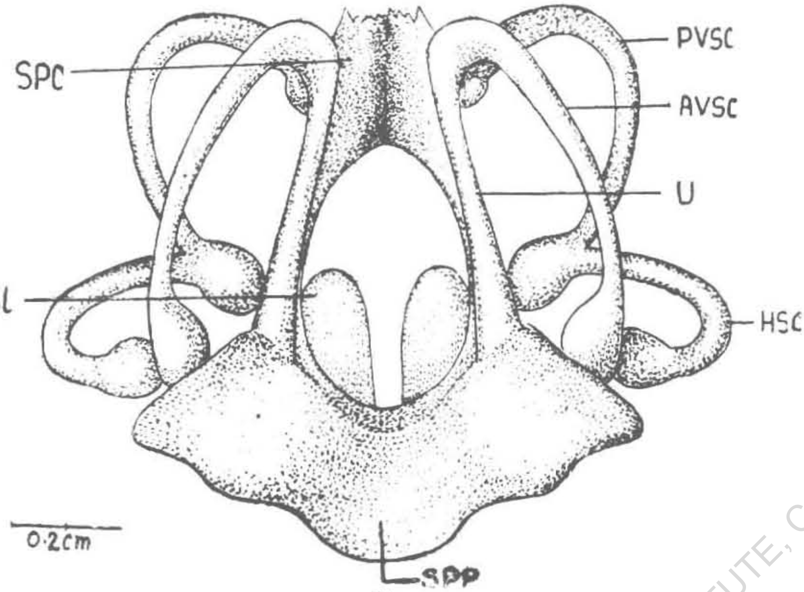
Pterotics :—The two pterotics (Figs. 14 and 15) are situated in the postero-lateral sides of the cranium. Towards the cerebral surface the lower region of this bone is excavated to form the posterior osseous bulla or the pterotic bulla. The outer and slightly raised portion of the pterotic bears a tunnel for the passage of the horizontal semicircular canal of the membranous labyrinth.

Epiotics :—These bones (Figs.16 and 17) occupy the postero-lateral boundary of the cranium above the exoccipitals. Posteriorly each of them is perforated by a longitudinal tunnel for the passage of the posterior vertical semicircular canal.

Parasphenoid :—It is a median rod-like bone (Fig. 7, PSph) articulating anteriorly with the vomer. Posteriorly it gives out two extensive lateral wings (LPsph), extending beyond the basi-occipital.

Membranous Labyrinth

The membranous labyrinth (Figs. 18 and 19) which is lodged in the auditory recess on either side of the brain consists of three semi-circular canals, an anterior vertical (AVSC), a posterior vertical (PVSC) and a horizontal (HSC), generally arising from a median longitudinal tube the utriculus (U) or vestibule. In *Hilsa toli* the horizontal semicircular canal, however, arises directly from the ampulla of the posterior vertical semi-circular canal instead of from the utriculus. The horizontal and the posterior canals pass through the tunnels in the pterotic and epiotic bones respectively. The utriculus gives out posteriorly a rather elongated sac known as sacculus (Sl) which is antero-dorsally differentiated into a small lagena (L).



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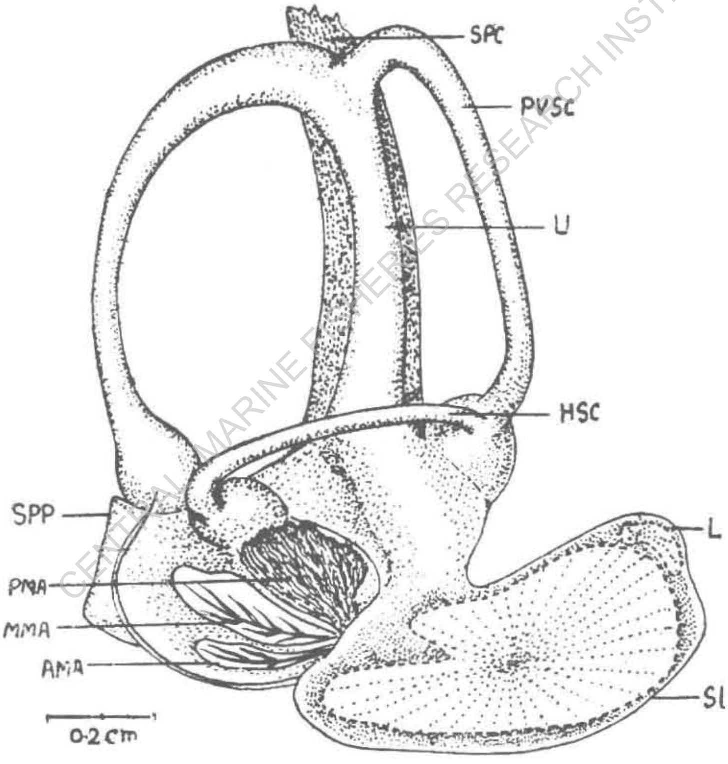

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FIG. 18—Anterior view of the membranous labyrinth of *Hilsa toli*.
FIG. 19.—Lateral view of the membranous labyrinth of *Hilsa toli*.
AMA anterior macula acustica; **AVSC** anterior vertical semicircular canal; **HSC** horizontal semicircular canal; **L** lagena; **MMA** middle macula acustica; **PMA** Posterior macula acustica; **PVSC** posterior vertical semicircular canal; **Sl** sacculus; **SPC** supracerebral perilabyrinthine canal; **SPP** subcerebral perilabyrinthine plate; **U** utriculus.

Ventrally the utriculus is directly connected with three structures known as maculæ acusticæ (Tracy 1920). The anterior of them (AMA) lies in front of the fenestra of the anterior osseous bulla ; the middle one (MMA), leaf-like in appearance, rests just over the fenestra (*de Beaufort 1909) and the posterior (PMA) looks like a large membranous fold. The three maculæ acusticæ meet ventrally and are innervated by the branches of the auditory nerve.

Both the membranous labyrinths are embedded in a fatty tissue intermingled with a connective tissue, to which the term perilabyrinthine tissue is applied. Ventrally this tissue is thickened to form a plate known as subcerebral perilabyrinthine plate (SPP). This plate is produced into wing-like expansions on either side. Laterally this plate closely adheres to the inner sides of the utriculi and thus joins the two membranous labyrinths. Over the medulla oblongata this perilabyrinthine tissue forms a canal (SPC) which descends along the cerebral surface of the utriculus on each side (Tracy 1920). In this way, it again unites the two membranous labyrinths.

Relation of the Air-bladder with the Membranous Labyrith

A very small cartilagenous tube (Fig. 20, CT′) bifurcating at its origin comes into contact with the outermost layer of the anterior extracoelomic end of the air-bladder. The inner wall of the anterior end of the air-bladder leads into its lumen, where the bladder gives rise to two very narrow air-ducts or precoelomic diverticuli (Fig. 21, PCD). These air-ducts enter in front into the two branches (CT″) of the cartilagenous tube which proceed over the lateral wings of the parasphenoid in the direction of the two exoccipitals. In this region the precoelomic diverticulum runs along the extra cranial groove found in the lower part of the exoccipital. This groove is converted into a canal by the extension of a part of the cartilagenous tube.

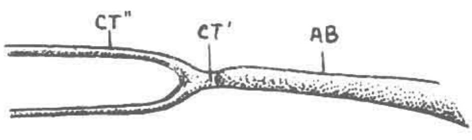

Fig. 20—Diagramatic representation showing the anterior end of the air-bladder establishing a close contact with the short cartilagenous tube which bifurcates anteriorly.
AB air-bladder ; CT′ small cartilagenous tube ; CT″ bifurcated cartilagenous tube.

The precoelomic diverticulum enters through a pin-point aperture into the bulla in the exoccipital, where it dilates into a small fusiform enlargement. Anteriorly it divides into two branches. One of them enters the anterior osseous bulla forming a dilated air-vesicle (AV) and the other into the posterior osseous bulla forming another air-vesicle (PV). The anterior air-vesicle is bigger than the posterior. Except for the single aperture for the entrance of the air vesicle, the posterior osseous bulla has no other aperture through which the vesicle can come into contact with the membranous labyrinth.

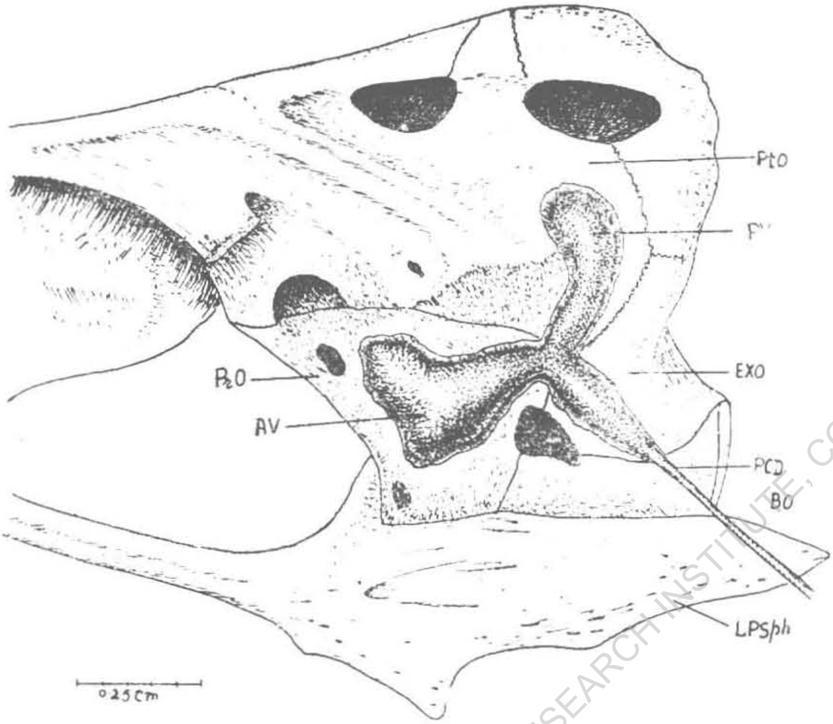

FIG. 21.—Precœlomic duct and the air-vesicles in the anterior and posterior osseous bullæ.
AV anterior air-vesicle ; BO basioccipital ; EXO exoccipital ; LPSph lateral wing of parasphenoid ; PrO Pro-otic ; PtO pterotic ; PCD precœlomic diverticulum ; PV posterior air-vesicle.

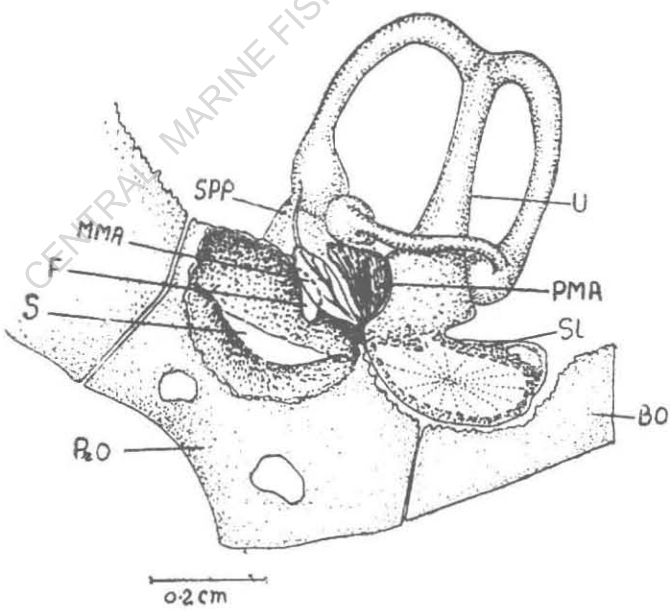

FIG. 22.—Anterior osseous bulla exposed laterally to show the relation between the air-vesicle and the membranous labyrinth.
BO basioccipital ; F fenestra ; MMA middle macula acustica ; PrO pro-otic ; S septum ; Sl sacculus ; SPP subcerebral perilabyrinthine plate ; U utriculus.

The anterior osseous bulla in the pro-otic is a spacious cavity divided into two compartments by a transverse septum (Fig. 22, S). In the lower compartment lies the air-vesicle that enters the bulla while the upper compartment opens into the cranial cavity through an elongated fenestra (F).

According to Weber* (1820) a diverticulum from the utriculus enters the anterior osseous bulla through the fenestra and comes in contact with the air-vesicle. This results in the union of these two structures, whereby the so-called transverse septum comes into existence. This septum throughout its circumference adheres to the inner wall of the bulla and resembles the tympanic membrane.

Ridewood (1891) also supports Weber's conception and states that a diverticulum or a cæcum from the utriculus enters the anterior osseous bulla through the fenestra. Soon after its entrance in the capsule, it enlarges into a planoconvex chamber. Its flat surface gets apposed to the air-vesicle and forms the transverse septum. Naturally if the air-vesicle is separated from the septum which is said to be formed by the union of the air-vesicle and the cæcum of the utriculus, the remaining portion should be the utricular diverticulum.

Breschet* (1938), Hasse* (1873) and Retzius* (1881) assert that the utricular diverticulum does not enter the anterior osseous bulla. Tracy (1920) mentions that the three-sided thickening of the utricular wall which Tysowski called " the diverticulum of the utriculus " is no other thing than the thickening of the perilabyrinthine tissue in the form of a triangular plate. Thus he disproves the direct ear-swimbladder relationship in the Clupeoids.

The utricular diverticulum referred to by Weber and Ridewood has not been observed in *Hilsa toli* during the present investigation. It appears that the membranous labyrinth does not come in contact with the anterior air-vesicle directly and its connection with the air-bladder is probably brought about through the agency of perilymph, entering the anterior osseous bulla through the fenestra. This perilymph is separated from the air-vesicle by the transverse septum mentioned above. The changes in the gaseous contents of the air-bladder are most probably transmitted along the air vesicle to the fibrous septum in the anterior osseous bulla and thence through the perilymph to the endolymph of the membranous labyrinth.

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Reprinted from the Journal of the University of Bombay,
Volume XXIII, Part 5, March 1955.

A COMPARATIVE ACCOUNT OF THE AIR-BLADDER AND THE MEMBRANOUS LABYRINTH IN SOME MARINE FISHES

By

D. V. Bal, P. D. Nayak & M. R. Varde

(Zoology Laboratory, Institute of Science, Bombay)

Introduction

THE air-bladder in Clupeoid fishes has always aroused interest among the Zoologists, owing to its diversity of form and function. In these fishes the bladder is indirectly connected with the membranous labyrinth as described in our earlier paper (1955). The present paper deals with a comparative account of these two structures in about 20 Clupeoid species belonging to the genera, *Hilsa*, *Sardinella*, *Kowala*, *Ilisha*, *Opisthopterus*, *Dussumieria*, *Nematolosa*, *Anodontostoma*, *Thrissocles* and *Coilia*. The latter two belong to the family Engraulidae whereas the others belong to the family Clupeidae.

All these fishes are Physostomous by nature of their air-bladder. The bladder is always simple, single chambered sac devoid of retia mirabilia and oval, a highly vascular structure.

In all these fishes the air-bladder sends two precoelomic diverticuli through two cartilagenous tubes towards the base of the skull and these on entering the skull give rise to air vesicles, which ultimately come in contact with the perilympatic fluid surrounding the internal ear.

The membranous labyrinth of these fishes is also peculiar. The two labyrinths are connected with each other in two ways, the common one being by a perilabyrinthine plate joining them in the anteroventral region. In the other type, in addition to this plate, there is an arch-like perilabyrinthine canal connecting the two labyrinths. All these features of the air-bladder and the membranous labyrinth are dealt with in detail in *Hilsa toli*, the other fishes having been treated from comparative view point only.

Reprinted from the Journal of the University of Bombay, Volume XXVII, Part 3, November, 1958.

AIR-BLADDER

Genus-*Hilsa*, species-*Hilsa toli* (Cuv. and Val)

The air-bladder (Fig. 1 AB) of *Hilsa toli* is a simple fusiform membranous sac, placed at an acute angle with the vertebral column (VT.). It is dull white in appearance and covered by a black pigmented peritoneal membrane (PM) ventrally. A short narrow pneumatic duct (PD) arises from the ventro-mesial wall of the bladder and opens anteriorly into the stomach

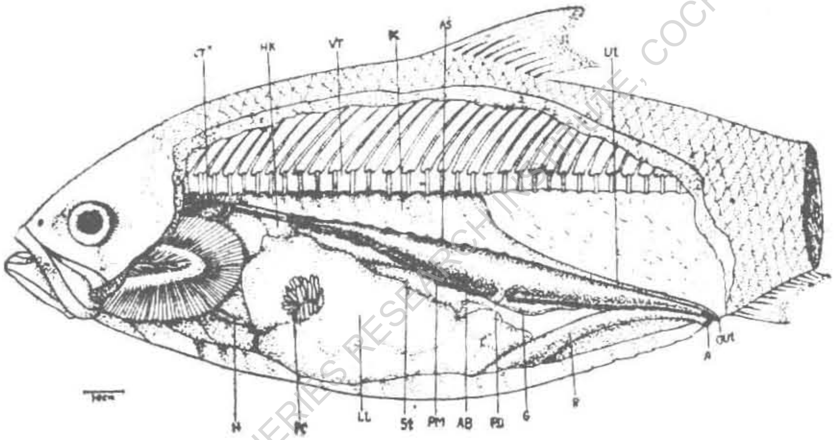
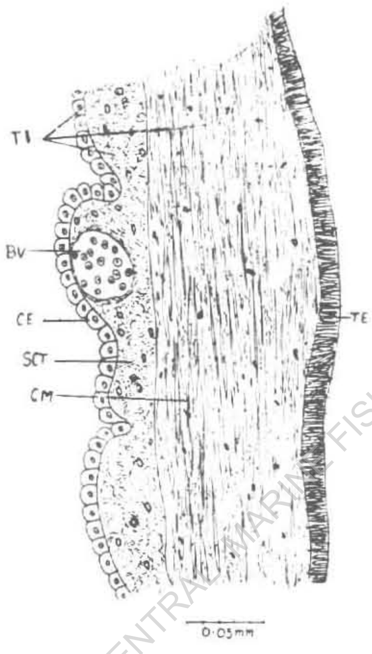


Fig. 1 Air-bladder and its relation with the general viscera in *Hilsa toli*.

Dorsally the air-bladder is in contanct with the kidney (K). In the pericardial region the narrow end of the bladder is laterally shielded by the head kidney (HK). Between the kidney and the air-bladder there extends a strong aponeurotic sheath (AS), that covers the intercostal spaces. This sheath forms a protective tube around the delicate anterior end of the air-bladder. Posteriorly there are two aponeurotic sheaths which are connected with the bladder by means of connective tissue.

The anterior extra-coelomic end of the air-bladder comes in contact with a small cartilagenous tube which soon bifurcates into two (CT"). The anterior end of the bladder entering the cartilagenous tube is very thin, as it is composed of only the inner wall of the air-bladder. This extra-coelomic end of the air-bladder divides to give rise to two diverticuli, each of which passes through the corresponding branch of the cartilagenous tube proceeding to the base of the skull. There the precoelomic diverticulum enters the ex-occpital bone and dilates into small fusiform enlargement which terminally bears two dilated air vesicles. The anterior one of these is lodged in a spacious osseous bulla of the prootic bone and the posterior one in the pterotic bone.

Histologically the wall of the air bladder consists of two main layers, the tunica interna (Figs. 2 and 3 TI) and the tunica externa (TE). The tunica interna is composed of a single layer of cuboidal epithelium CE), a layer of spongy connective tissue (SCT) and a broad layer of circular muscles (CB). The tunica externa consists of radially arranged slightly loose fibrous connective tissue.



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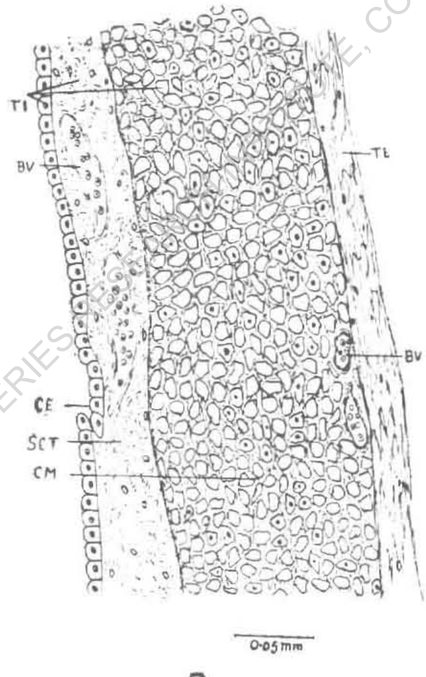

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Fig. 2 Transverse section of the air-bladder of *Hilsa toli*.

Fig. 3 Longitudianl section of the air-bladder of *Hilsa toli*.

In Clupea, Tracy (1920) mentions about a submucosal layer of loose connective tissue between the tunica interna and the tunica externa. In *Hilsa toli* this tissue (SCT) occupies the space between the muscular and epithelial layers of the tunica interna.

In *Hilsa ilisha* (Ham) the aponeurotic sheaths are well developed and extend backwards over the bladder to a considerable extent.

Genus—*Sardinella*.

Species—*S. longiceps* (C. and V.), *S. albella* (C. and V.) and *S. fimbriata* (C and V.).

Three species of this genus, namely *S.longiceps* (Fig. 4) *S.albella* and *S.fimbriata* were available for comparison. Except for the indented appearance of the bladder in the postero-dorsal wall and the origin of the pneumatic duct (PD) far behind, the air-bladder in these species shows no other difference from that of *H.toli*.

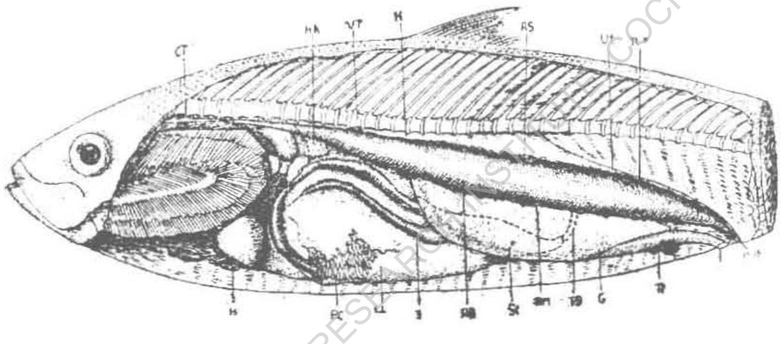


FIG 4

Fig. 4 Air-bladder and its relation with the general viscera in *Sardinella longiceps*.

Genus—*Kowala*.

Species—*K. coval* (C).

In *Kowala coval*, the only species of this genus, the air-bladder is almost parallel to the vertebral column and its dorsal wall shows a number of rounded projections.

Genus—Ilisha.

Species—*I filigera* (C. and V.), *I. elongata* (Bennette) and *I.motius* (Ham)

The air-bladder of these fishes shows remarkable differences in comparison with those of the previously described species.

The air-bladder in *I.filigera* (Fig. 5) and *I.elongata* is long and tubular with a silvery appearance. Unlike in the former three genera the air-bladder of these two species is traversed by shining bands running obliquely over it at regular intervals. Anteriorly it is flattened and is firmly applied against the ventral surface of the vertebral column as far back as the sixth vertebra. Behind, it gives rise to two appendages one of which is posterior (PAP) running along the left side of haemal spines and the other is ventral (VAP). The posterior appendage which is blind makes its way through a canal formed by the abdominal muscles.

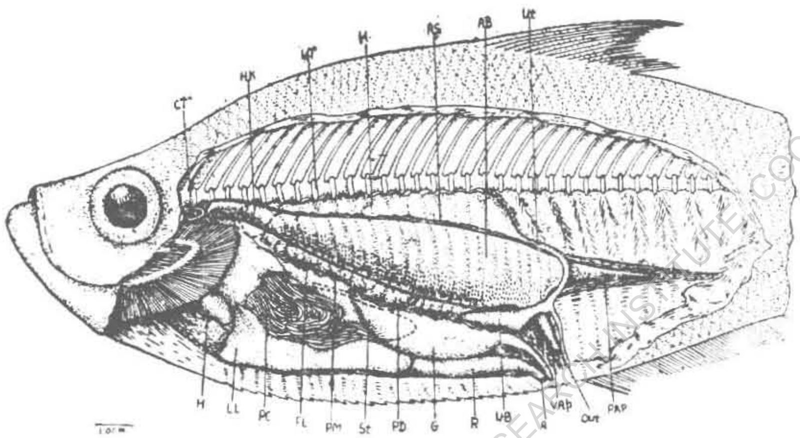


Fig. 5 Air-bladder and its relation with the general viscera in *Ilisha filigera.*

The ventral appendage (VAP) proceeds downwards and opens to outside by an irregular opening. Bennette (1879) also observed a similar structure in the Herring and assures that it affords a freer passage for the gases than the pneumatic duct.

The aponeurotic tissue of these two *Ilisha* species neither forms a protective tube round the anterior end of the bladder, nor loose lateral sheaths posteriorly, as in *Hilsa*. The bifurcated cartilagenous tubes and the precoelomic diverticula are comparatively short.

In *I. motius* (Fig. 6) the air-bladder is not flattened anteriorly and remains free from the anterior vertebrae unlike that in the other two species of *Ilisha*. The posterior appendages also are absent in this species.

A number of variations are also noticed in the histological structure of the bladder of *Ilisha*. In all the three species the tunica interna (*Fig. 7 TI*) is comparatively very narrow while the tunica externa is many times broader than that in *H. toli*. In between these two layers

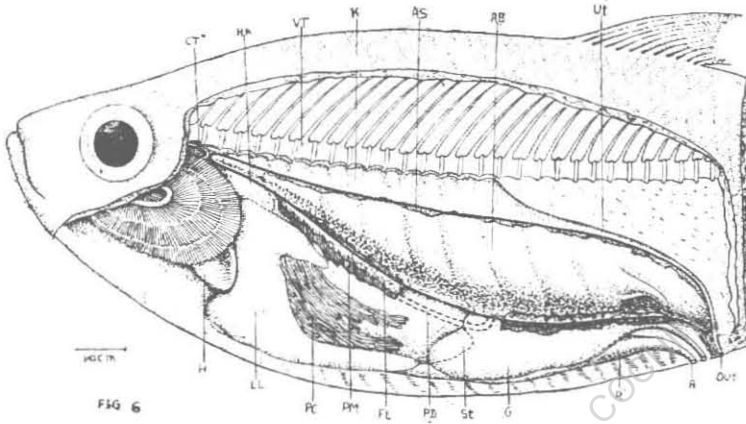


Fig. 6 Air-bladder and its relation with the general viscera in *Ilisha motius*.

there is a spongy connective tissue forming the so called sub-mucosal layer mentioned by Tracy (*op.cit*). The epithelium is of the squamous type and not cuboidal as in *Hilsa*.

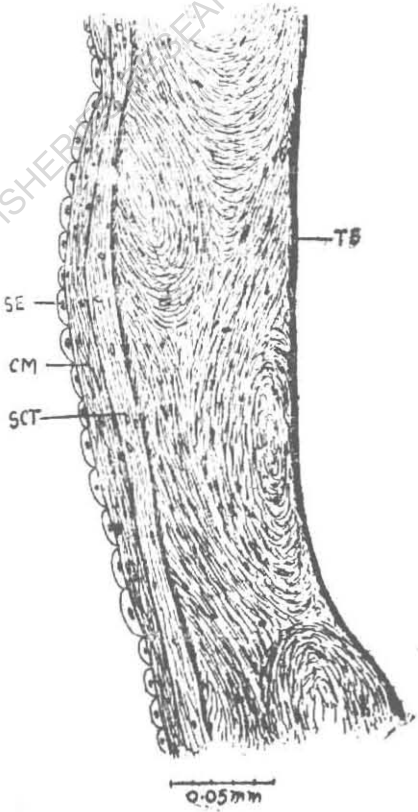


Fig. 7 Transverse section of the air-bladder of *Iligera filigera*.

Genus—*Opisthopterus*

Species—*O. tardoore* (C).

The air-bladder of *O.Tardoore* (Fig. 8) is more like that of *Ilisha*. Anteriorly it is free as in *I. motius*. Posteriorly the bladder bears three appendages (PAP) as against two in *I. filigera* and *I. elogata*. One of these is ventral (VAP) and the other two run along the lateral sides of the haemal spines in that region. At the level where the posterior appendages are given off (Fig. 9) the ureter pierces the dorsal wall of the air-bladder, runs along the inner wall of the same and coming out of it runs parallel to the postero ventral appendage.

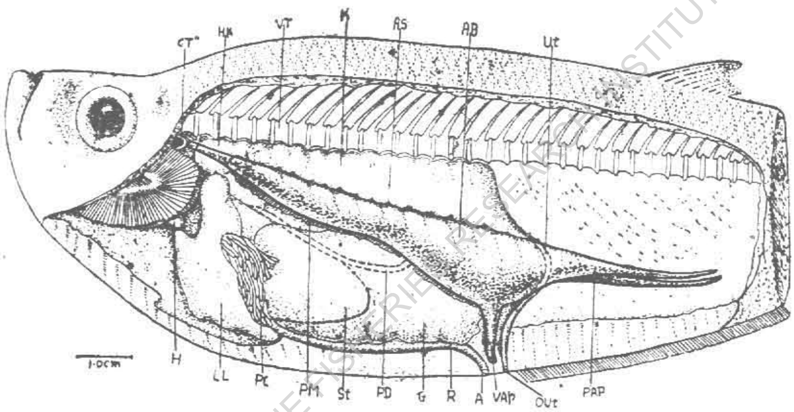


Fig. 8 Air-bladder and its relation with the general viscera in *Opisthopterus, tardoore*.

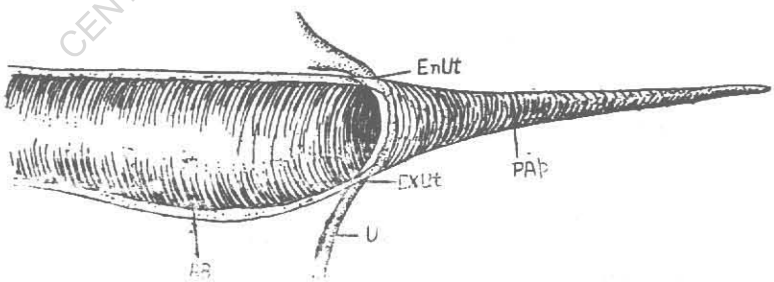


Fig. 9 Diagrammatic representation showing the passage of the ureter on the inner side of the air-bladder of *Opisthopterus tradoore*.

Genera—Dussumieria, Nematolosa and Anodontostoma.

The air bladder of *Dussumieria hasselti* (Bleeker), *Namatalosa nasus* (Bloch) (Figs. 10 and 11) and *Anodontostoma chachunda* (Ham) (variety of *Chatoessus selanghat*), shows close resemblance to that of *Hilsa*. In *Dussumieria hasselti* the short pneumatic duct arises far anteriorly. The loose spongy tissue mentioned above is also altogether absent.

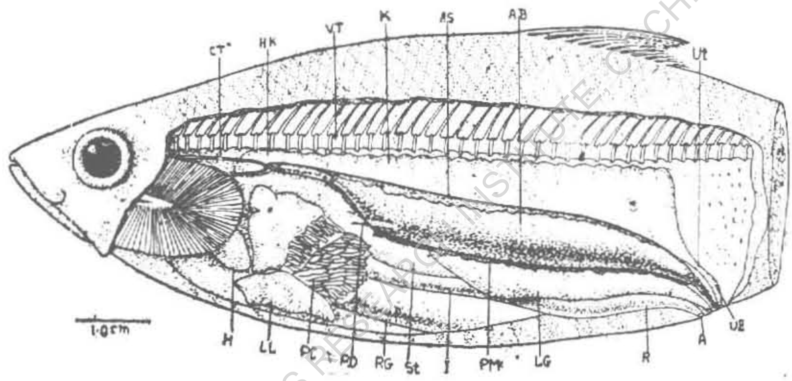


Fig. 10 Air-bladder and its relation with the general viscera in *Dussumieria hasselti*.

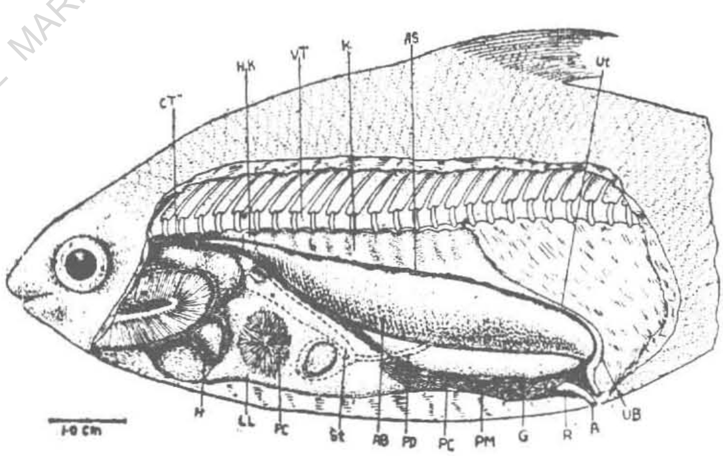


Fig 11 Air-bladder and its relation with the general viscera in *Nematalosa nasus*.

Genus—*Thrissocles.*

Species—*T. hamiltoni* (Gray) *T. mystax* (Schneider) *T. malabaricus* (Bloch), *T. dussumieri* (C. and V.) *T. setirostris* (Broussonet) and *T. purava* (Ham).

The air-bladder (Fig. 12) in the above species of *Thrissocles* shows some characters of *Sardinella* and *Kowala* and a few of *Ilisha*. The air-bladder in these fishes is silvery and shining as in *Ilisha* and most of its dorsal wall bears rounded projections (RP) as in *Sardinella* and *Kowala*.

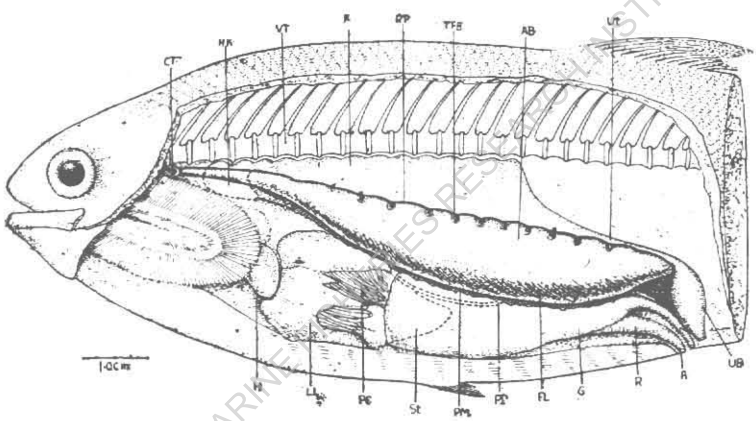


Fig 12 Air-bladder and its relation with the general viscera in *Thrissocles hamiltonii.*

There is no support for the anterior end of the bladder. The spaces between the rounded dorsal projections are traversed by stout rod like transverse ligamentous bars (TFB.) joining the two body walls. This is the only real anchorage for the bladder. These rounded projections and the transverse bars are absent in *T.dussumieri* (Fig. 13 AB) and *T. setirostris*. The cartilagenous tubes are long as in *Hilsa*, *Sardinella* and *Kowala*.

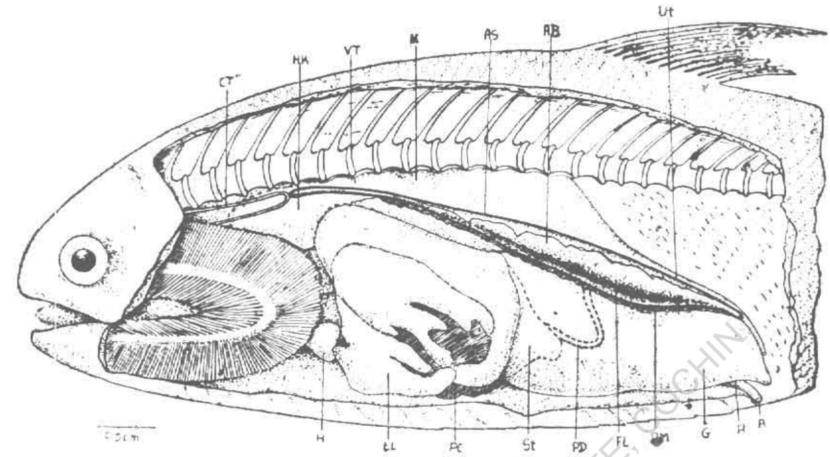


Fig 13 Air-bladder and its relation with the general viscera in *Thrissocles dussumieri*.

In *T. malbaricus* the air-bladder (Fig. 14) extends nearly to the base of the skull and its dorsal projections are very prominent.

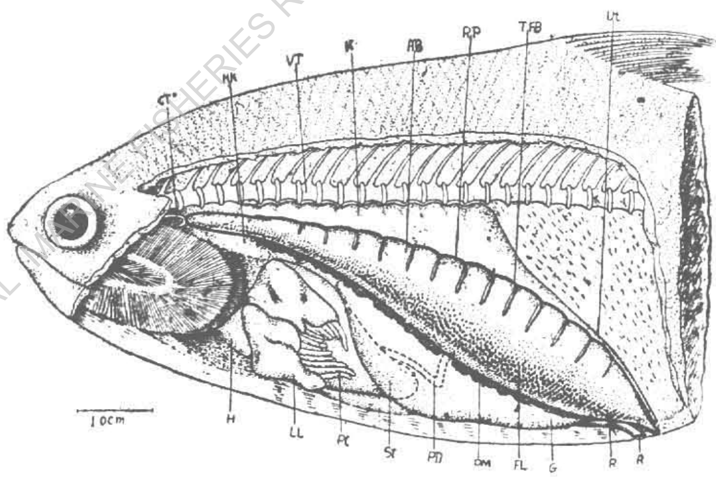


Fig. 14 Air-bladder and its relation with the genral viscera in *Thrissocles malabaricus*.

In *T. purava* (Fig. 15 a) the bladder is usually flat, thick and with a narrow lumen. The tunica externa is wrinkled. The shape of the bladder appears to undergo various changes in accordance with its air-contents. Sometimes the anterior part (*a*), sometimes the middle (*b*) and sometimes the posterior part of the bladder (*c*) appears to be dilated. In some cases the fully dilated bladder shows a median constriction.

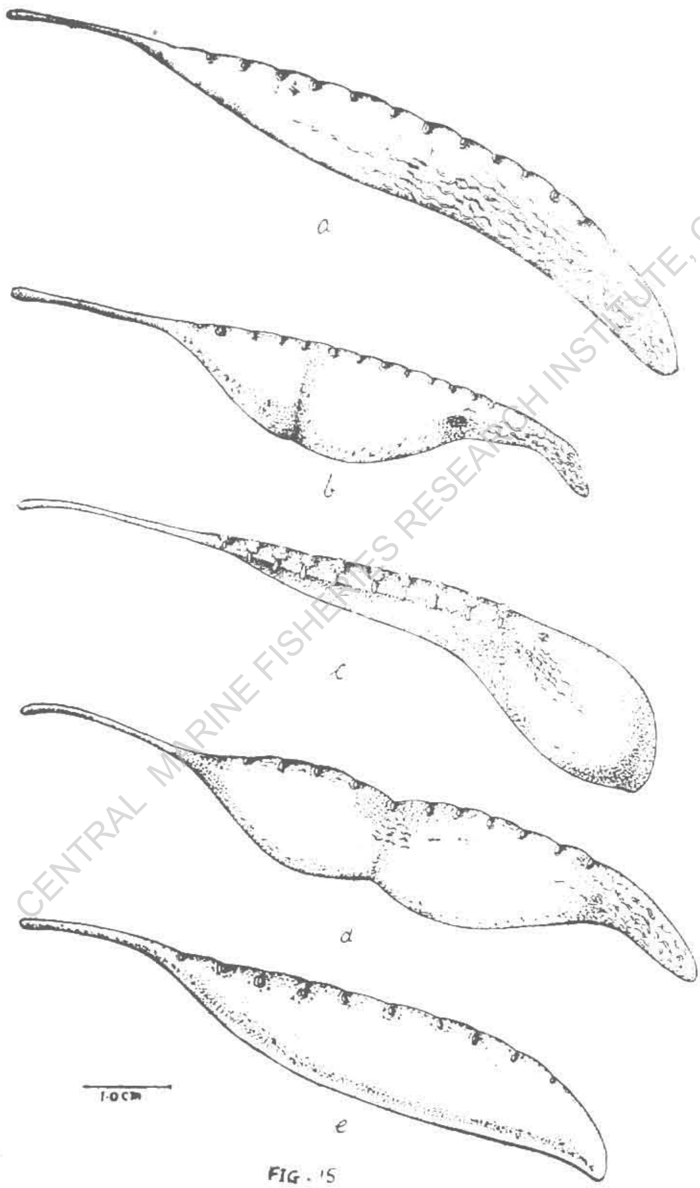


FIG. 15

Fig. 15 Variations found in the shape of the air-bladder of *I. purava*.

The muscle layer (Fig. 16) of tunica interna is well developed as compared to that in *Ilisha*. The internal epithalium is cuboidal as in *Hilsa*. The tunica externa is similar to that of *Ilisha* but comparatively narrow. The submucosal layer is well developed.

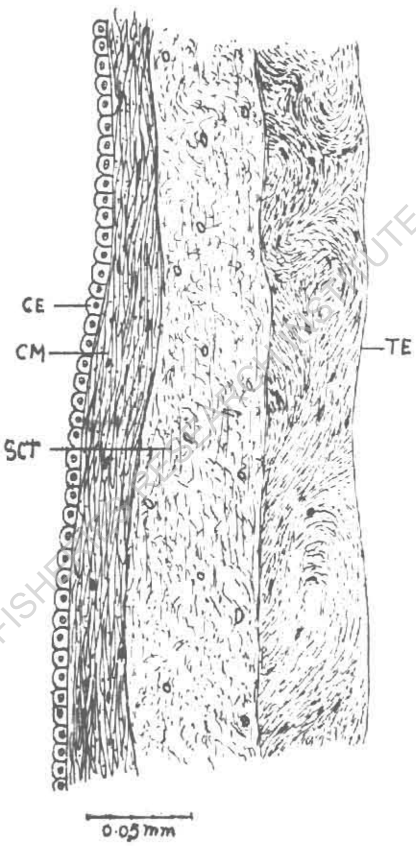


Fig. 16 Transverse section of the air-bladder of *Thrissocles hamiltonii*.

Genus—*Coilia*,

Species—*C. dussumieri* (C and V.)

The air-bladder of *Coilia dussumieri* (Fig. 17 A B) is similar in appearance to that of *Ilisha* and *Thrissocles*. The anterior end is very close to the skull and rounded, the posterior one being somewhat narrow.

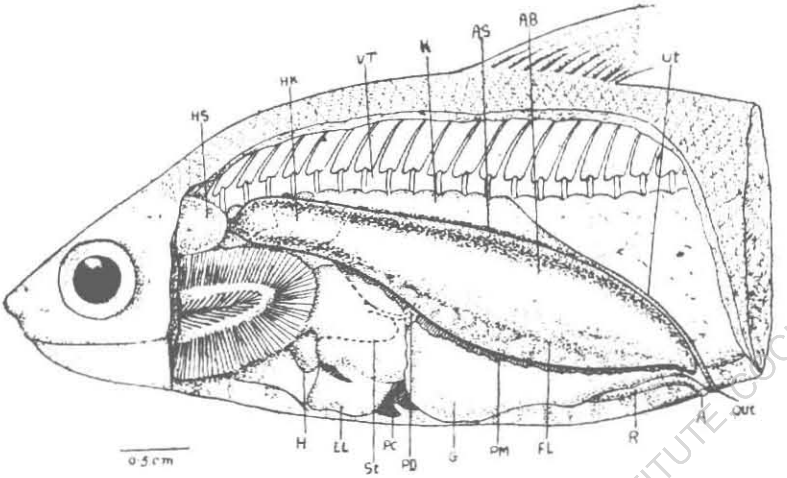


Fig. 17 Air-bladder and its relation with the general viscera in *Coilia dussumieri.*

Histologically the bladder almost resembles that of *Ilisha* except that the submucosal spongy layer and tunica externa are much thicker. The aponeurotic sheath is not well developed. The cartilagenous tube are short and bear numerous outgrowths.

MEMBRANOUS LABYRINTH.

Hilsa toli (C. and V.) : The membranous labyrinth (Figs. 18, 19) lodged in the auditory recess on either side of the brain has a median longitudinal tube known as ultriculus (U) which generally gives rise to three semicircular canals, an anterior vertical (AVSC), a posterior vertical (PVSC) and a horizontal (HSC). In *H. toli* the horizontal semi-circular canal rises directly from the ampulla of the posterior semi-circular canal instead of from the utriculus. The horizontal and posterior canals pass through the tunnels in the pterotic and epiotic bones respectively. The ultriculus gives out posteriorly an elongated sac known as sacculus (SL) which in the antero-dorsal region is differentiated to form the legena (L). Ventrally the utriculus is directly connected with three structures known as *macula acusticae* (Tracy, 1920) The anterior (AMA) and the middle accustica (MMA) are leaf-like in appearance while the posterior one (PMA) is in the form of a membranous fold. All these three macula acusticae meet ventrally and are innervated by the branches of the auditory nerve.

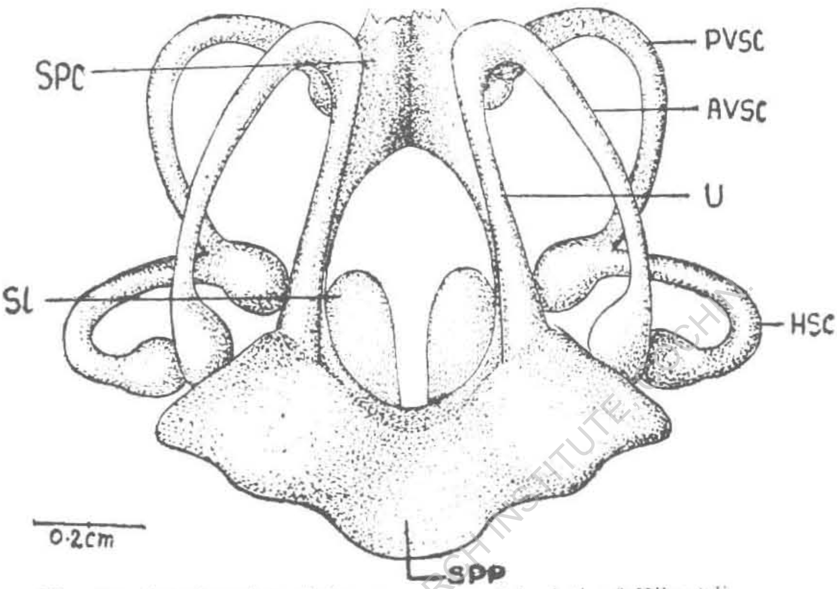


Fig. 18 Anterior view of the membranous labyrinth of *Hilsa toli*.

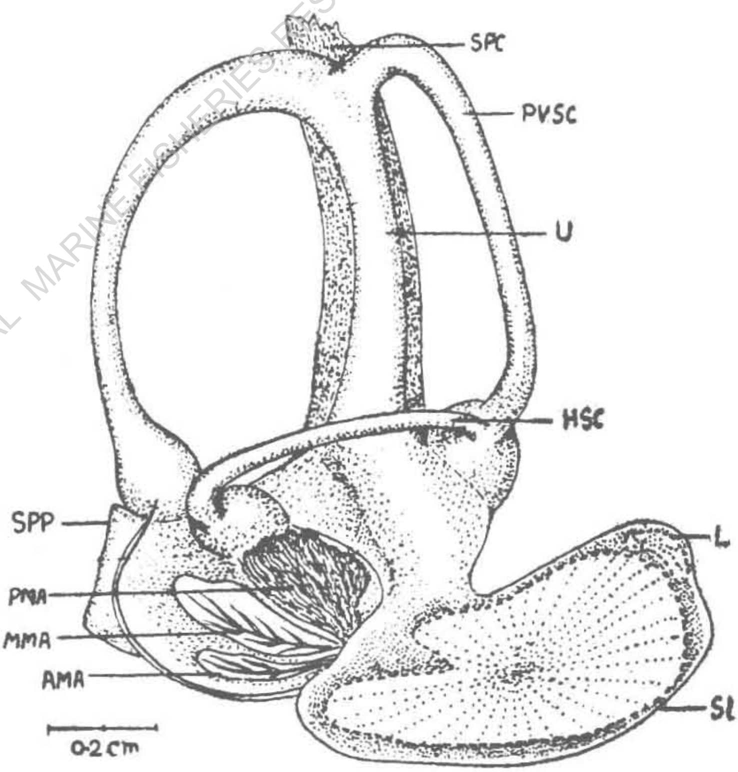
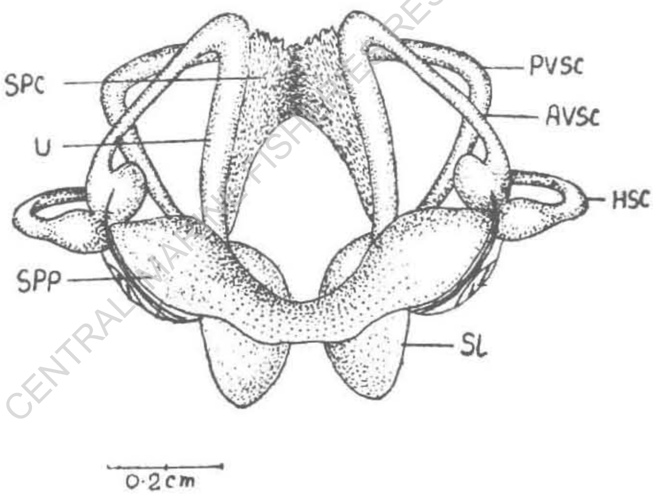


Fig. 19 Lateral view of the membranous labyrinth of *Hilsa toli*

Both the labyrinths are embedded in a fatty tissue intermingled with connective tissue, to which the term perilabyrinthine tissue is applied. Ventrally it gets thickened to form a broad plate known as subcerebral perilabyrinthine plate (SPP). The two ends of this plate closely adhere to the inner sides of the two utriculi and thus join the two membranous labyrinths. An arch-like supracerebral perilabyrinthine canal (SPC) formed in the perilabyrinthine tissue starts from the inner surface of one utriculus, goes over the medulla and descends along the inner side of the other utriculus. The two membranous labyrinths are thus again united. Tracy (1920) also mentions about a similar connection in clupeoids.

The membranous labyrinths of *H. ilisha*, *S. albella*, *S. fimbriata*, *K. coval*, *N. nasus* and *A. Chachunda* (Variety of *Chatoessus selanghat*) do not show any variation from that of *H. toli*.

The membranous labyrinth of *S. longiceps* (Fig. 20) is shorter and broader than that in *H. toli*. The semi-circular canals, especially the horizontal and the posterior vertical, do not show regular curving as in *H. toli* but show deep bends corresponding to the nature of the tunnels in pterotic and epiotic bones respectively. The subcerebral perilabyrinthine plate joining the two labyrinths is not well developed.



Big. 20 Anterior view of the mebranous labyrinth of *Sardinella longiceps*.

The horizontal semi-circular canal (Fig. 21) in *I. filligera* arises directly from the utriculus which is not the case in *H. toli*. The subcerebral perilabyrinthine plate is comparatively narrow but its two ends in the region of the utriculi are more thickened. Supracerebral perilabyrinthine canal is present as in *Hilsa*. The membranous labyrinth in *I. elongata*, *I. motius* and *O. tardoore* does not show any structural variation from that of *I. filigera*.

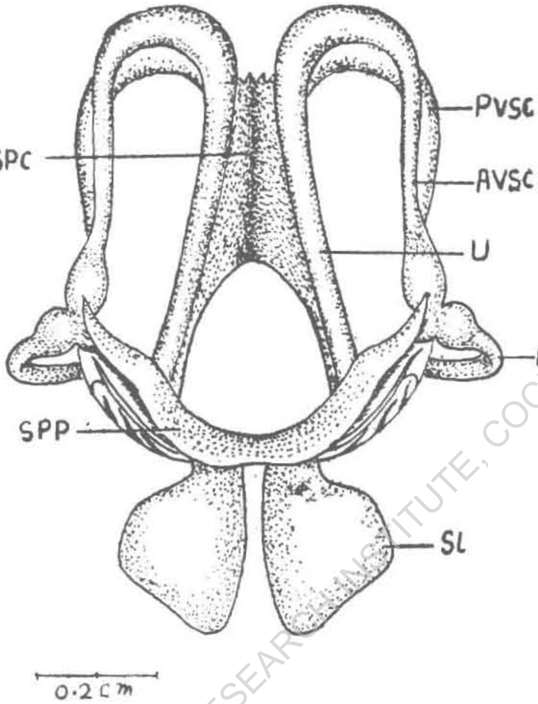


Fig. 21 Anterior view of the membranous labyrinth of *Ilisha filigera*.

The membranous labyrinth of *Dussumieria hasselti* (Bleeker) (Fig. 22) characteristically differs from those previously described, because of the absence of the supracerebral perilabyrinthine canal.

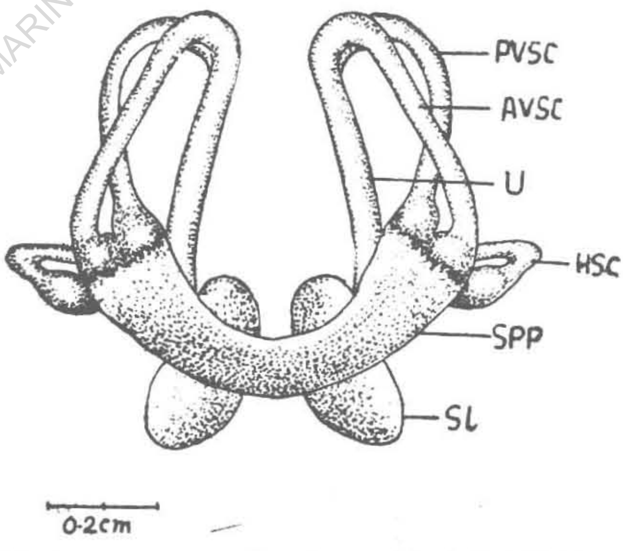


Fig. 22 Anterior view of the membranous labyrinth of *Dussumieria hasselti*.

The membranous labyrinth of *T. hamiltonii* (Fig. 23) resembles that of *Dussumieria* in that the two labyrinths are united only by a single transverse subcerebral perilabyrinthine plate (SPP), the supra-cerebral perilabyrinthine canal being absent. The area occupied by the three canals and the utriculus is smaller than that occupied by the sacculus. The horizontal semi-circular canal arises directly from the ampulla of the posterior vertical semi-circular canal (PVSC) as in the case of *H.toli*.

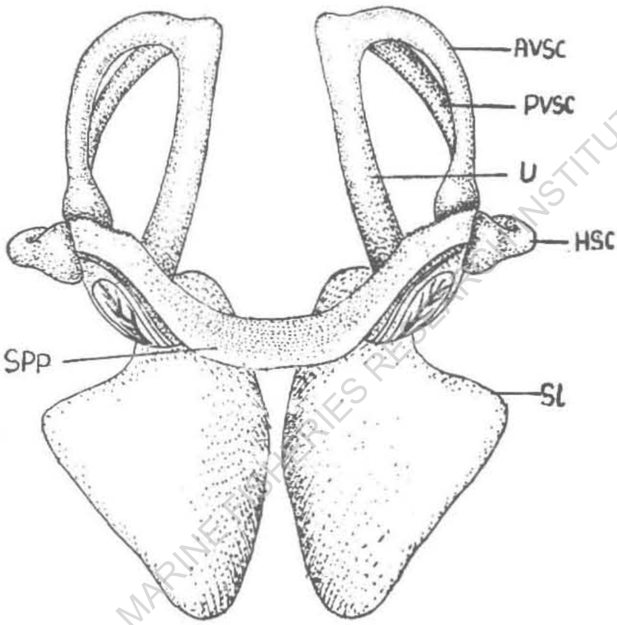


Fig. 23 Anterior view of the membranous labyrinth of *Thrissocles hamiltonii*

The other species of *Thrissocles*, namely *T. mystax*, *T. malabaricus*, *T. dussumieri*, *T. setirostris* and *T. purava* have similar type of membranous labyrinths.

Due to the flattened nature of the cranium in *Coilia dussumieri*, the cavity in which the membranous labyrinth is lodged, becomes much restricted. The two labyrinths (Fig. 24) together appear very broad. As in *Thrissocles* the saccular region is more spacious. The posterior semicircular canal is the shortest and anterior vertical the longest. The horizontal canal arises from the ampulla of the posterior vertical canal. The canals as well as the utriculus are very narrow and delicate. A distinct lagena and only two macula acusticae are noticed. The labyrinths are united together in the same way as in *H.toli*. The perilabyrinthine canal is well-defined and has a greater diameter.

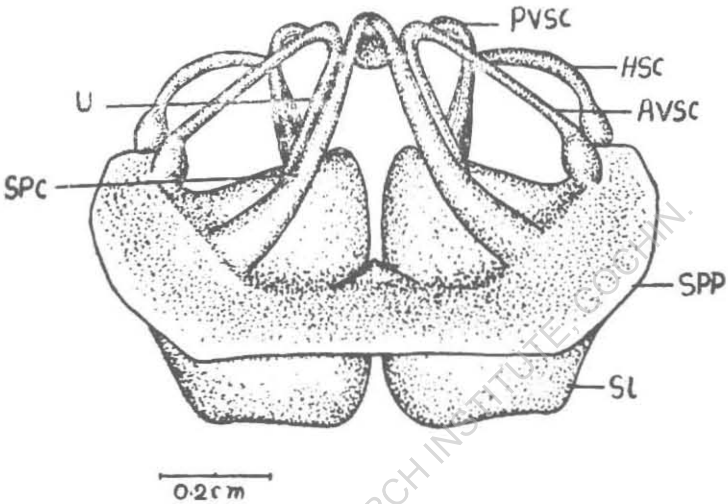


Fig. 24 Anterior view of the membranous labyrinth of *Coilia dussumieri*.

SUMMARY

1. The air-bladder of the fishes under study is a simple single chambered sac devoid of retia mirabilia and oval.

2. Histologically, the air-bladder has two main layers—the tunica interna and the tunica externa. Internally the tunica interna is lined by cuboidal epithelium in all the genera excepting *Iisha*, *Opisthopterus* and *Coilia* where it is replaced by the squamous epithelium. The tunica externa is very narrow with loose fibres in all excepting *Ilisha*, *Opisthopterus*, *Thrissocles* and *Coilia* where it is broader and more compact.

3. The aponeurotic tube around the anterior delicate end of the bladder is present only in *Hilsa*, *Sardinella*, *Kowala*, *Dussumieria*, *Nematolasa* and *Anadontostoma*.

4. Excluding *T. dussumieri* and *T. setirostris*, in all the other *Thrissoctes* species described, transverse fibrous bars from the body walls afford strong anchorage to the bladder.

5. The bladder of *I. filigera* and *I. elongata* has one blind appendage in the posterior direction and another open one in the ventral direction In *O. tardoore* there are two blind posterior appendages.

6. The precoelomic diverticuli from the anterior end of the bladder on entering the skull give rise to air-vesicles.

7. In *D. hasselti* and the species of the genus *Thrissocles the* membranous labyrinths are connected together by means of subcerebral perilabyrinthine plate only, while in the rest of the fishes under discussion there is an arch-like supracerebral perilabyrinthine canal in addition to this plate.

Acknowledgement

We are thankful to Shri V. B. Masurekar, Research Assistant in Zoology at the Institute of Science, Bombay, for willing assistance in preparation of this paper.

List of Abbreviations

A	—anus.
AB	—air-bladder.
AMA	—anterior macula acustica.
AS	—aponeurotic sheath.
AVSC	—anterior vertical semi-circular canal.
BV	—blood vessels.
CE	—cuboidal epithelium.
CM	—circular muscle.
CT	—bifurcated cartilagenous tube.
EnUt	—entrances of the ureter into the air-bladder.
ExUt	—exit of the ureter from the air-bladder.
FL	—layer of fat.
G	—gonad
H	—heart.
HK	—head kidney.
HS	—hind region of skull.
HSC	—horizontal semi-circular canal.
I	—intestine.
L	—lagena.
LG	—left gonad
LL	—liver lobe.
M	—mesonephros.
MMA	—middle macula acustica.
OUT	—opening of ureter.
PAP	—posterior appendage.
PC	—pyloric caecae.
PD	-pneumatic duct.
PM	—peritoneal membrance.
PMA	—posterior macula acustica.
PVSC	—Posterior vertical semi-circular canal.
R	—rectum.
RG	—right gonad.
RP	—indented appearance.
RU	—recessus utriculus.
SI	—sacculaus
St	—stomach
SCT	—sopngy connective tissue.

SE —squamous epithelium.
SPC —supracerebral perilabyrinthine cannal.
SPP —subcerebral perilabyrinthine plate.
TE —tunica externa.
TFB —transverse fibrous bars.
U —utriculus.
Ut —ureter.
YB —urinary bladder.
VAp —ventral appendage.
VT —vertebral column

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Reprinted from **"INDIAN JOURNAL OF FISHERIES"** Vol. 6, Pp. 280-297

SOME ASPECTS OF THE FISHERY AND BIOLOGY OF *POLYDACTYLUS INDICUS* (SHAW)

By

(Miss) P. D. Nayak

Reprinted from "Indian Journal of Fisheries", Vol. VI, No. 2, 1959

SOME ASPECTS OF THE FISHERY AND BIOLOGY OF *POLYDACTYLUS INDICUS* (SHAW)

BY (MISS) P. D. NAYAK

(Central Marine Fisheries Research Station)

INTRODUCTION

ONE of the commercially important fisheries of the Bombay and Saurashtra waters is that of *Polydactylus indicus* locally known as 'Dara'. Preliminary observations on the biology and fishery of *P. indicus* have been recorded by Mohamed (1955). The food and feeding habits of this species are described by Karekar and Bal (1958). The present investigations were undertaken with a view to obtaining more information regarding the fishery and biology of this important species. This paper deals with the data collected on the catches of trawlers working from Bombay, during the years 1950–57, supplemented by observations made at a few of the other centres where a good fishery for this fish exists. During this period different types of trawlers were operating from Bombay. *Taiyo Maru No.* 17 operated Otter-trawl from 1951–54. The Cutters *M.T. Ashok* and *M.T. Pratap* used Otter-trawls during 1950–53 and then they together formed into a pair of Bull-trawlers from 1953–57. In addition to these, two more pairs of Bull-trawlers, namely, *Satpati-Pilotan* and *Arnalla-Paj* started operating during 1956–57.

MATERIAL AND METHODS

P. indicus occurs in the Bombay and Saurashtra waters, extending from Bombay up to the Gulf of Cutch. For the length and growth studies, specimens brought by the trawlers from the Dwarka region were utilized in view of the fact that the quantities of this fish landed by the trawlers from other regions were very negligible and often erratic. During the seven years commencing from 1950, the number of months of fishing in the Dwarka region during one fishing season ranged from two to six and each of the Otter-trawlers as well as a pair of Bull-trawlers had been able to make only two voyages per month. Hence, the length-frequency measurements are limited in number and restricted to a few months in each year. To obtain comparative data, some measurements have been made on the catches from Satpati (60 miles north of Bombay), Sachana near Jamnagar (Saurashtra) and also on the specimens brought to the local market and Government cold storage at Sassoon Dock (Bombay) for freezing.

Maturing specimens from the Bombay, Cambay and the Gulf of Cutch regions have been examined to study the spawning behaviour and fecundity of this fish.

The 'Dara' Fishery Off the Bombay and Saurashtra Waters

The Bombay and Saurashtra waters have been divided into five regions, namely, Bombay, Cambay, Veraval, Porbandar and Dwarka, as indicated in Fig. 1. Each region is further divided into a number of rectangles of

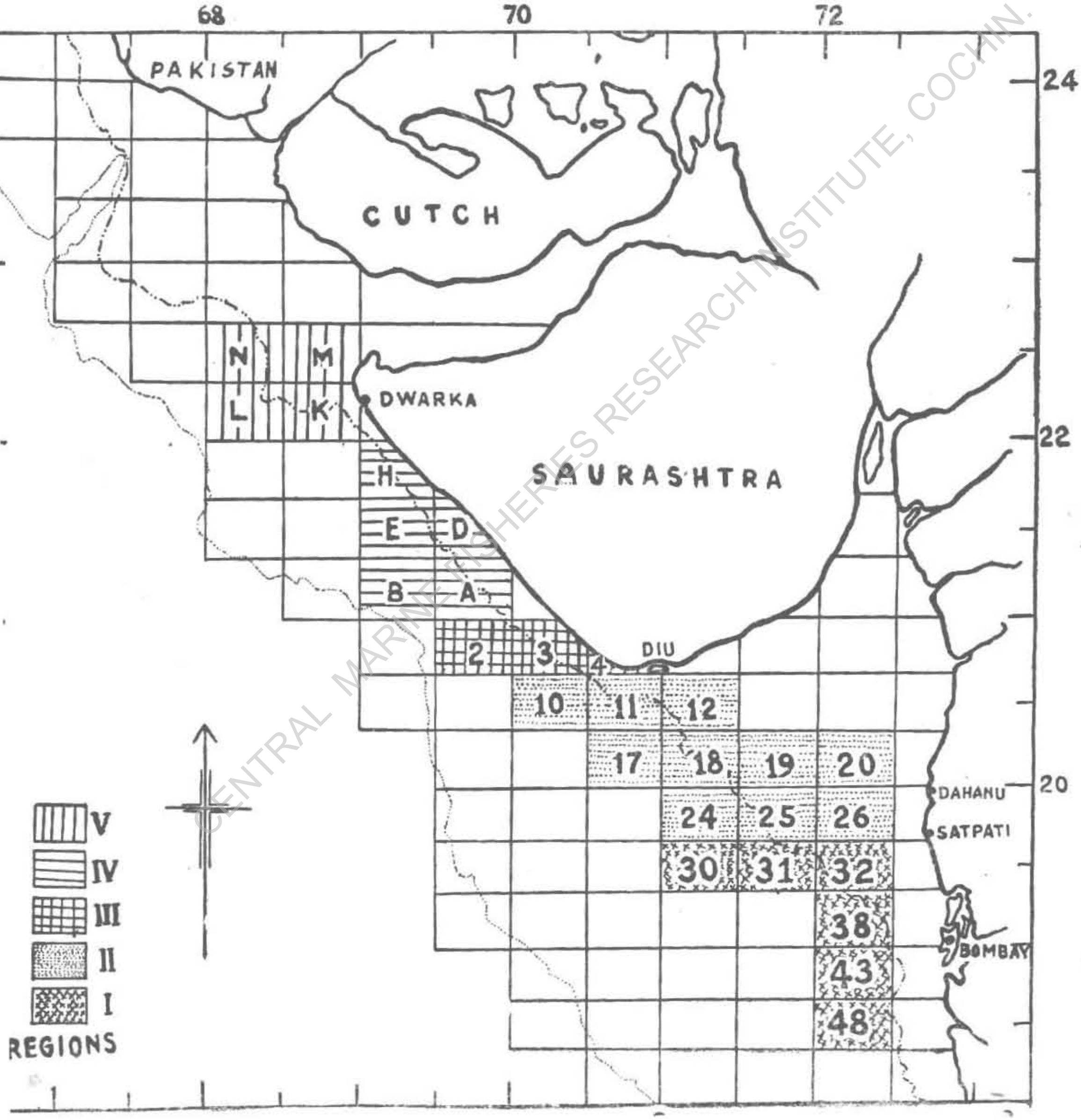

FIG. 1. The areas and regions of the Bombay and Saurashtra waters fished by the trawlers.

600 sq. miles each and have been termed as areas. They are denoted either by numbers or by letters for convenience.

The areas fished (Jayaraman *et al.*, 1955) fall into the following regions:

I.	Bombay Region	48, 43, 38, 32, 31, 30.
II.	Cambay Region	26, 25, 24, 20, 19, 18, 17, 12, 11, 10.
III.	Veraval Region	4, 3, 2.
IV.	Porbandar Region	A, B, D, E, H.
V.	Dwarka Region	K, L, M, N.

The fish landed by the trawlers *M.T. Ashok* and *M.T. Pratap* from 1950–51 to 1956–57 has been examined for 'Dara' and the estimated quantity of 'Dara' landed in each year in relation to the total catch has been given in Table I.

TABLE I

Percentage of 'Dara' in the total landings of M.T. Ashok *and* M.T. Pratap *from* 1950–51 to 1956–57

Year	Total landings in kg.	'Dara' landings in kg.	Percentage of 'Dara'
1950–51	187,298	42,900	22·9
1951–52	213,435	34,833	16·3
1952–53	199,339	25,484	12·8
1953–54	366,875	95,145	25·9
1954–55	212,570	26,115	12·3
1955–56	326,028	61,835	19·0
1956–57	182,194	45,540	25·0

It may be seen from the above table that 'Dara' fishery supported by only one species forms one of the major trawl fisheries on the Bombay and Saurashtra Coast. During the seven years under study, the catches fluctuated from 12·8 to 26·0% the average being 19·1%. The maximum quantity of 'Dara' amounting to nearly a quarter of the total catch were landed during 1953–54.

In order to make the results of trawling in different regions comparable the catch per hour of trawling in terms of kilogrammes has been calculated and presented in Table II. During 1950–51, the trawlers restricted their fishing activity to only three regions namely, Bombay, Cambay and Veraval; the maximum of 39,435 kg. of 'Dara' was caught from the Cambay region giving an average of 10·1 kg./hr. of fishing. A further examination of the area-wise analysis shows that even in this region most of 'Dara' were caught from areas 18, 19, 24, 25 and 26, indicating thereby the relative richness of these areas.

TABLE II

Catch per hour of 'Dara' fishing in kg. from the five different regions by the Cutters M.T. Ashok *and* M.T. Pratap, *during* 1950–51 *to* 1956–57

Year	Mode of operation	Catch per hour of 'Dara' fishing in kg.				
		I	II	III	IV	V
1950–51	Otter-trawling	5·8	10·1	4·7	No fishing	
1951–52	Do.	4·2	8·7	0·6	0·5	29·2
1952–53	Do.	2·9	4·0	3·0	0·0	21·4
1953–54	Bull-trawling	4·8	5·2	0·3	1·5	195·0
1954–55	Do.	0·0	3·9	4·7	2·5	322·5
1955–56	Do.	1·0	7·3	1·7	0·3	269·6
1956–57	Do.	0·5	0·0	0·0	3·3	187·6

During the next two years, *i.e.*, from 1951–52 to 1952–53 the Cutters worked in all the five regions. During these years the maximum 'Dara' catches were obtained from the Dwarka region with an average of 29·2 kg. and 21·4 kg. per hour of fishing. From 1953–54 onwards the Dwarka region continued to be the best fishing ground for 'Dara' in all the successive years. The 'Dara' catches during these years were of very high order, *i.e.*, 94,377 kg. in 1953–54; 25,444 kg. in 1954–55; 60,246 kg. in 1955–56 and 45,455 kg. in 1956–57. The average catch per hour of trawling in these years worked out to 195·0 kg., 322·6 kg. and 187·6 kg. respectively. This sudden improvement in 'Dara' catches may possibly be due to the change over of the fishing method from Otter-trawling to Bull-trawling.

A study of Table II clearly indicates the abundance and high productivity in region V in respect of 'Dara' as compared to the other regions. A detailed study of the area-wise distribution of this region as presented in Fig. 2 shows that the areas K and M contributed more 'Dara' although small quantities were also taken from areas L and N. The depth in areas K and M varies between 20 and 51 metres.

The fishermen of Satpati and Dahanu undertake 'Dara' fishing as a major fishing operation from December to April by using bottom-set gill-nets. They land 'Dara' in large quantities from the Bombay and Cambay regions.

Coming to the size of 'Dara' in the landings, it is seen in the local as well as in the trawl fishing that Bombay and Cambay regions yield large-sized 'Dara' in the maturing condition. Specimens of 'Dara' with gonads in advanced stages of development have not been recorded from these regions; however, spent ones do occur in small numbers. Young immature ones popularly known as 'Chelna' have been noticed only as stray specimens in the fish landings and do not form a fishery in these regions. In April 1956 *M.T. Ashok* landed immature 'Dara' from area No. 11 (Diu Head) in the Cambay region. Those 'Chelna' caught in one haul weighed 644 kg. and entirely comprised of the 34·5 cm. size-group. It may be of interest to emphasize here that the catches from Dwarka region, the richest trawling ground for 'Dara', comprise entirely of an immature stock of 'Dara' varying between 23·0 and 96·5 cm. in length. Only once, however, *M.T. Ashok* landed a specimen of 103·3 cm. in length from this region (January 1957).

Table III shows the percentage of fully grown 'Dara' and the immature 'Chelna' in the various trawler landings from 1950–51 to 1956–57.

It is obvious from this table that excepting the first three years of the operation of the Cutters, the percentage of immature 'Chelna' is very high and varies from 92·0 to 99·0%.

The low percentage during the three years from 1950–51 to 1952–53 is probably due to the fact that they did not fish in the Dwarka region during 1950–51 and in the next two years they fished there during the dwindling season for this species.

A detailed analysis shows that the high percentage of 'Chelna' in the trawler catch was mainly from the Dwarka fishing grounds. It appears that the Dwarka region serves as a nursery ground for this species. The best season for exploiting this ground appears to be from November to March and after that the fishery dwindles.

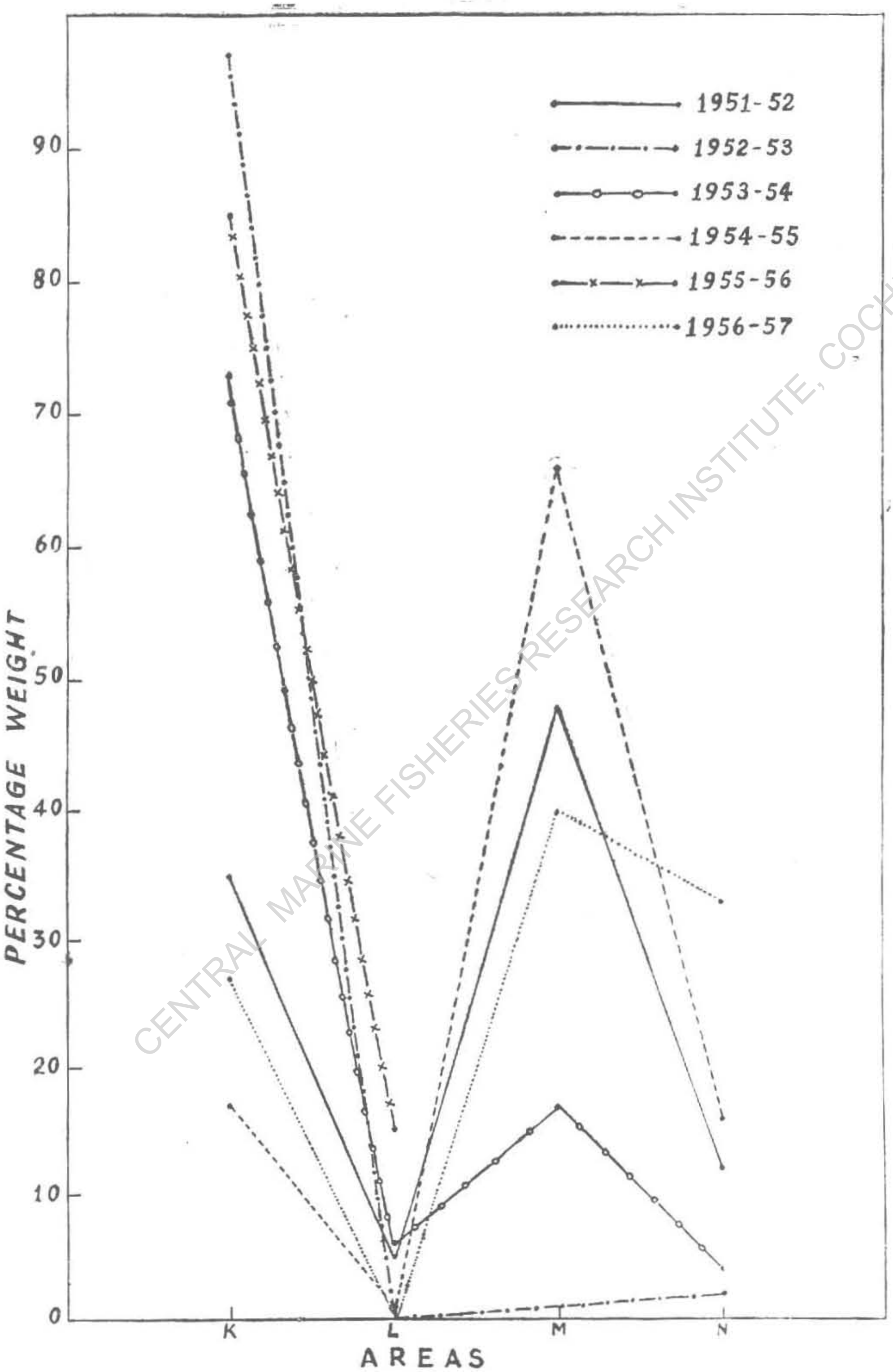

FIG. 2. Percentage distribution of 'Dara' in the different areas of Dwarka region during 1950–51 to 1956–57.

TABLE III

Percentage of fully grown ('Dara') and immature ('Chelna') individuals of P. indicus *in the total landings of* Taiyo Maru No. 17, M.T. Ashok *and* M.T. Pratap *and New India Fisheries Trawlers from* 1950–51 *to* 1956–57

Name of the vessel	Mode of operation	Year	Quantity of 'Dara' landed in kg.	Fully grown 'Dara'		'Chelna'	
				kg.	%	kg.	%
Taiyo Maru No. 17	Otter-trawling	1951–52	95,864	7,472	7·8	88,392	92·2
	Do.	1952–53	164,723	10,254	6·2	154,469	93·8
	Do.	1953–54	128,690	3,773	2·9	124,917	97·1
M.T. Ashok and *M.T. Pratnp*	Do.	1950–51	42,900	42,900	100·0	..	..
	Do.	1951–52	34,833	29,432	84·5	5,401	15·1
	Do.	1952–53	25,484	16,087	63·2	9,397	36·8
	Bull-trawling	1953–54	95,146	769	0·8	94,377	99·2
	Do.	1954–55	26,145	698	2·7	25,447	97·3
	Do.	1955–56	61,835	538	0·9	61,297	99·1
	Do.	1956–57	45,540	40	0·1	45,500	99·9
New India Fisheries Trawlers	Do.	1956–57	267,313	7,040	2·6	260,273	97·4

At Sachana, a fishing village in the Gulf of Cutch near Jamnagar, there exists a 'Dara' fishery from February to May when bottom-set gill-nets are employed in fishing. Large-sized mature and spawning 'Dara' specimens have been observed in these catches in the month of April.

Table IV indicates the 'Chelna' catch in kg. per hour of fishing and its percentage in the total catch by the Cutters in each year from 1951–52 to 1956–57. It is noticed that there is no appreciable decline in the 'Chelna' fishery of this region and that the productivity has been uniformly maintained.

It is too premature to correlate this high percentage of 'Chelna' yield from the Dwarka region with the decline in the 'Dara' fishery observed in

TABLE IV

'Chelna' catch in kg. per hour of fishing and its percentage in the total landings from Dwarka region by the Cutters M.T. Ashok *and* M.T. Pratap *during* 1951–52 *to* 1956–57

Year	Mode of operation	Fishing hours	Total catch in kg.	'Chelna'		
				kg.	c/h	%
1951–52	Otter-trawling	185·1	15,659	5,401	29·2	34·7
1952–53	Do.	439·7	26,263	9,397	21·4	35·7
1953–54	Bull-trawling	483·9	302,223	94,377	195·0	31·2
1954–55	Do.	78·9	69,575	25,447	322·5	36·5
1955–56	Do.	224·9	164,548	60,626	269·6	36·8
1956–57	Do.	248·3	146,663	45,455	187·6	30·9

recent years in the waters nearer Bombay. The reasons for this have not been obvious as the identity or otherwise of the two 'Dara' stocks has yet to be established. Detailed studies on raciation and migratory habits of this species may throw more light on this problem.

LENGTH-FREQUENCY STUDIES

The thread-like prolongations of the caudal lobes found in this fish even above 50·0 cm. in length are invariably broken. Therefore, the measurements are taken in terms of furcal length instead of total length. The specimens measured, varied between 5·0 and 119·0 cm. in length. For the length-frequency studies the lengths are grouped with 10·0 cm. intervals.

P. indicus landed at Versova, Satpati and Dahanu are not suitable for the growth studies as the gear used by these fishermen is a bottom-set gill-net (locally known as 'Waghur Jal'). It is a highly selective gear with a mesh size approximately 19·0 cm. knot to knot and 'Dara' of only above 80·0 cm. in length are caught in this.

Table V gives an idea of the percentage of different sizes obtained in this gill-net. It is noticed from this that the 89·5 to 99·5 cm. size-group appears to be predominant in this catch.

TABLE V

Percentage frequency of P. indicus *in the local landings during* 1954–56

Size-group in cm.	Cold storage (Bombay)		Satpati fishing village		Sachana (Saurashtra)	
	No.	%	No.	%	No.	%
80·5– 89·5	120	14·0	32	21·0	10	7·0
89·5– 99·5	712	81·0	108	70·0	109	78·0
99·5–109·5	47	5·0	13	9·0	20	15·0

The 'Dol' a bagnet operated from Sassoon Dock, Worli, Danda Versova, etc., around Bombay brings stray specimens of young *P. indicus*. They appear in the catch in insignificant numbers and rarely form an appreciable percentage. In these catches 'Dara' as small as 5·6 cm. in length have been noticed. Fish up to 21·0 cm. in length have been noticed quite often; the largest, so far observed, measured 28·6 cm.

In all 3,376 specimens of *P. indicus* were measured from the Dwarka region from November 1953 to January 1957. This period includes four successive fishing seasons for 'Dara' by the trawlers. In view of the fact that the fishing has been restricted to only a few months during each season, it is difficult to explain the significance of different modes occurring in the size-frequency graphs. However, an attempt has been made to see whether a reasonable picture could be obtained.

In 1953–54, the 'Dara' season commenced in November 1953 and extended up to April 1954 covering a period of five months. Fig. 3 shows the size-frequency distribution during these five months. The mode '*c*' at 74·5 cm. in November 1953 disappears completely from this region in the coming months. In January and February 1954 the mode '*a*' at 34·5 cm. represents the first year class, attaining this size during the first year. The mode '*b*' at 54·5 cm. and '*c*' at 74·5 cm. in March 1954 can be said to be the second and third year classes. The growth during the second year is perhaps in the order of about 20·0 cm. in length. The mode 'a^{+}' at 44·5 cm. in April 1954 is the one which has completed its first year and is in the second year. Probably it may be the one and a half year old group. Based on the above assumptions, the mode '*c*' at 74·5 cm. of November

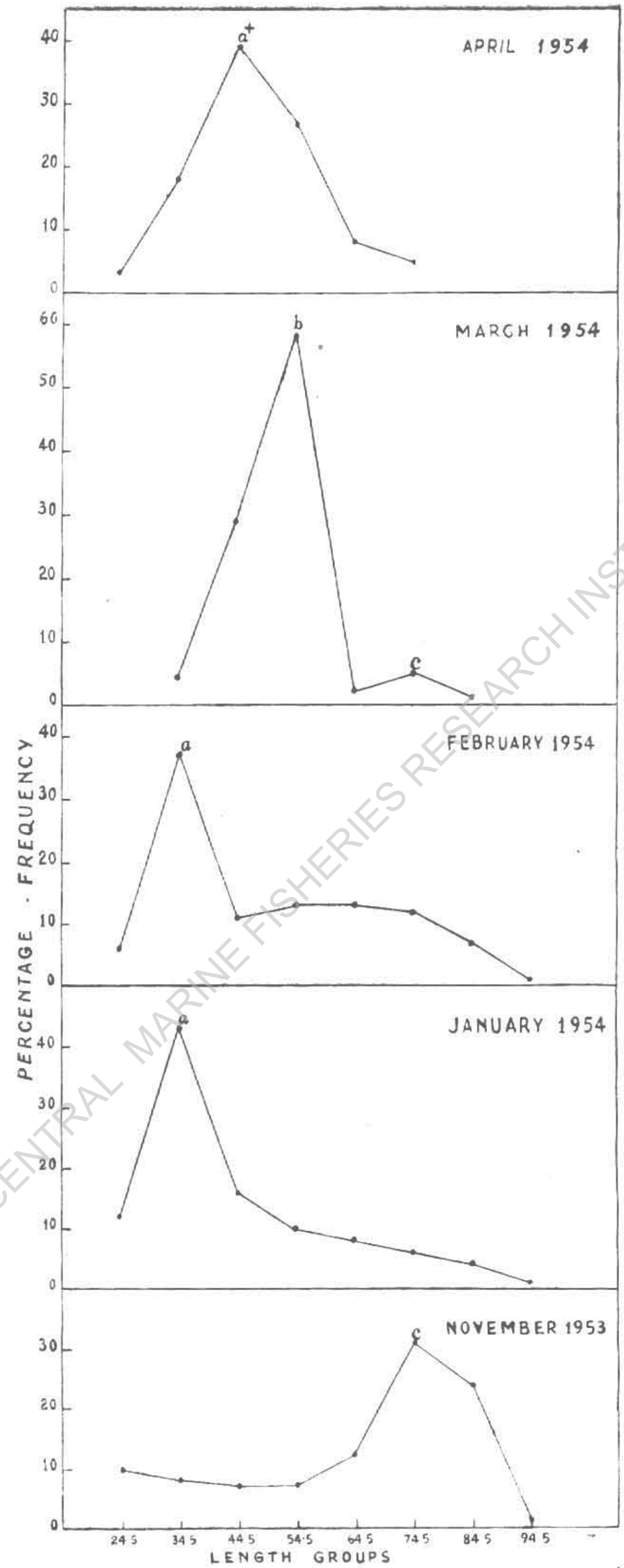

FIG. 3. Monthly size-frequency distribution of 'Dara' by the trawlers during 1953–54.

1953 can be considered as representing the third year class, the growth from second to third year also being in the order of about 20·0 cm.

In the second fishing season (Fig. 4) 'Dara' were landed during January and February 1955. In the January catch 'Dara' appeared in two size-

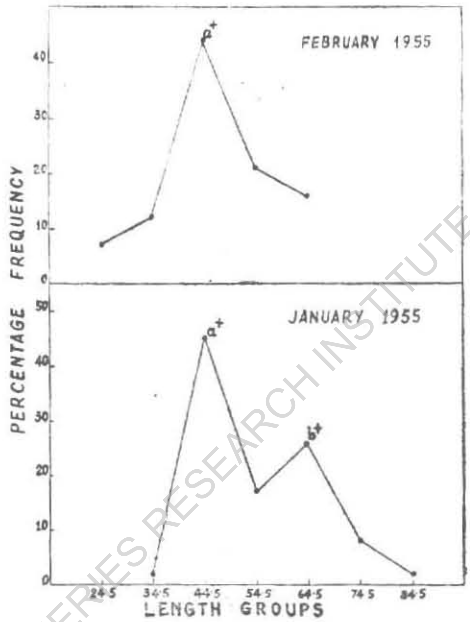

FIG. 4. Monthly size-frequency distribution of 'Dara' by the trawlers during 1955.

groups—one of the advanced first year class 'a^+' at 44·5 cm. and the other of advanced second year class 'b^+' at 64·5 cm. The February 'Dara' catch consisted of only advanced first year class.

During the third season (Fig. 5) *P. indicus* were recorded in December 1955, January and February 1956. During all these months, the catch comprised of two size-groups—one of the first year class with the mode 'a' at 34·5 cm. and the other of the advanced two or two and a half year class with the mode 'b^+' at 64·5 cm.

During the fourth season (Fig. 6) in November 1956 the second year class, in December 1956 the advanced first year and in January 1957 the first and second year classes were noticed.

AGE COMPOSITION OF THE CATCHES

From the data available for four seasons, it seems likely that the Dwarka 'Dara' catch consists of three-year classes, namely, the First, Second and Third year classes. However, the intermediate classes of advanced one year

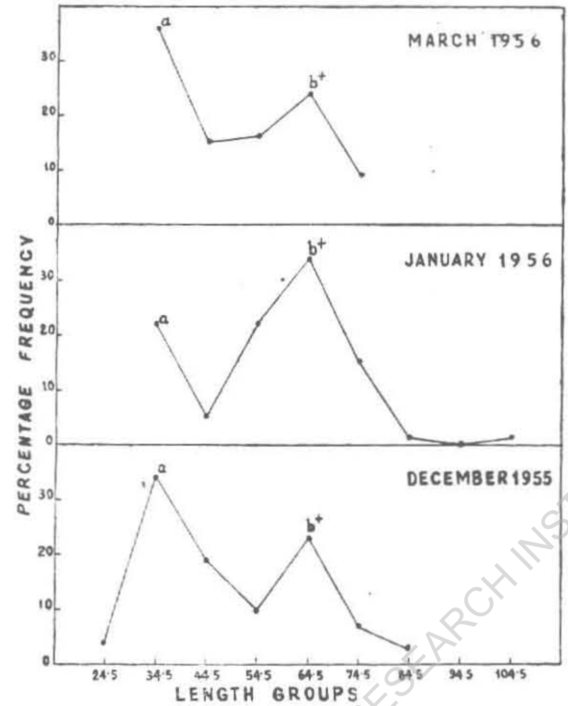

FIG. 5. Monthly size-frequency distribution of 'Dara' by the trawlers during 1955–56.

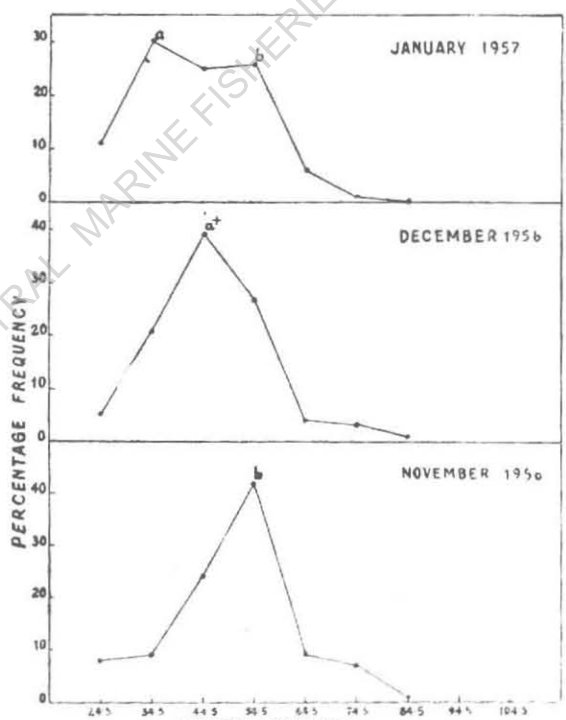

FIG. 6. Monthly size-frequency distribution of 'Dara' by the trawlers during 1956–57.

and advanced two-year classes which may as well be called as one and a half and two and a half year classes also appear. In any case excepting the only one specimen of 103·3 cm. caught by *M.T. Ashok*, fish above three years have not been obtained in the catches from this region. The fish obtained in the bottom-set gill-nets at Satpati, Dahanu, etc., from Bombay and Cambay areas and Sachana consist of sizes above 80·0 cm. Assuming that the stocks of 'Dara' in all the five regions is homogeneous, the dominant size-group of 89·6 to 99·5 cm. from the Bombay and Cambay areas may be assigned to the fourth year class.

SPAWNING SEASON OF *P. indicus*

The non-availability of mature and running *P. indicus* during the course of these investigations has made it difficult to trace its spawning season. Moreover, it is not possible to examine the gonadial condition throughout the year as the season lasts for a period of five to six months. Therefore, for studying the spawning periodicity of *P. indicus*, the ova diameter measurements had to be adopted. In this work, four stages of maturity have been recognized in the development of the ovary as against the seven stages described by the International Council for Exploration of the Sea. The four stages have been described below with the corresponding stages described by the International Council for ready reference.

Stage		Corresponding stages according to I.C.E.S.
I. Immature	The ovary is slender, thread-like and white in appearance. Ova are not visible to the naked eye. Ova are transparent with distinct nuclei in the centre. They measure from 0·0 to 0·30 mm. in diameter.	I & II
II. Maturing	The ovary is enlarged and yellow in colour. The eggs are granular in appearance and are visible to the naked eye. The ova are yellow and opaque—some in the commencement of formation of yolk and others full of yolk. Their size ranges from 0·31 to 0·62 mm. in diameter.	III & IV
III. Spawning	The ovary is full and light yellow in colour. It is in the oozing stage and the ova are liberated with the slightest pressure. The ripe ova are completely transparent with a single oil globule. The size of the ova varies from 0·63 to 1·10 mm. and oil globule varies from 0·26 to 0·40 in diameter.	VI
IV. Spent	The ovary is flabby and blood shot in colour.	VII

Remnants of the yolky eggs remain.

Stage V, described by the International Council for Exploration of Sea, was not availed for study during the course of this investigation. Hence, this stage could not be considered here.

Four specimens were examined for the study of ova diameter measurements. Three of them were in the maturing stage, collected one each in February 1956, June 1956 and September 1957 from the Bombay and Cambay regions. The fourth specimen collected at Sachana near Jamnagar in April 1954 was in the spawning condition. The frequency polygons of ova diameters from these four specimens of *P. indicus* have been shown in Fig. 7.

During February three modes '*a*', '*b*' and '*c*' at 0·14, 0·38 and 0·62 mm. are seen. In April also three modes can be made out. The mode '*c*' in February corresponds to the maturing ova and can be traced in April as ripe ova. In April the mode '*c*' is not prominent and is represented in two small modes. This may be due to the fact that the specimen being in the oozing condition, most of the ripe ova had already fallen from their follicles into the formalin. Therefore, it appears that the ova in respect of modes '*c*' and 'c^{+}' in April form one crop. The other two modes '*a*' and '*b*' of this month are at 0·22 and 0·54 mm. respectively. In June the mode '*b*' persists at 0·54 mm. and a fresh batch of immature eggs go to form a new mode 'a^{+}' at 0·14 mm. In September also the mode '*b*' persists at 0·54 mm. This month again a new batch of eggs is proliferated from the germinal layer to form a mode 'a^{+}' at 0·14 mm.

According to the spawning habits of the fishes described by Dejong (1939) and Prabhu (1956) it is seen from Fig. 7 that *P. indicus* spawns twice in a year. The April crop represented by the modes '*c*' and 'c^{+}' forms the first batch of eggs to be spawned. Moreover, in June spent individuals occur in good numbers. This fact is also supported by Mohamed (*loc. cit.*). And during monsoon the young ones appear as stray specimens in the landings of Sassoon Docks. These evidences prove the first spawning season of 'Dara' extending from April to June.

The possibility of having the second spawning season for 'Dara' can be supported by four factors. Firstly, the frequency polygons of ova diameters show the persistence of the mode '*b*' of maturing eggs at 0·54 mm. from April to September. This suggests the possibility of another spawning season for 'Dara' sometime between September and February for which the maturing eggs of mode '*b*' will be responsible. Secondly, in January 1956 and subsequently in January 1957 two young *P. indicus* of 6·0 and 5·6 cm. respectively in furcal length were collected from Versova. From

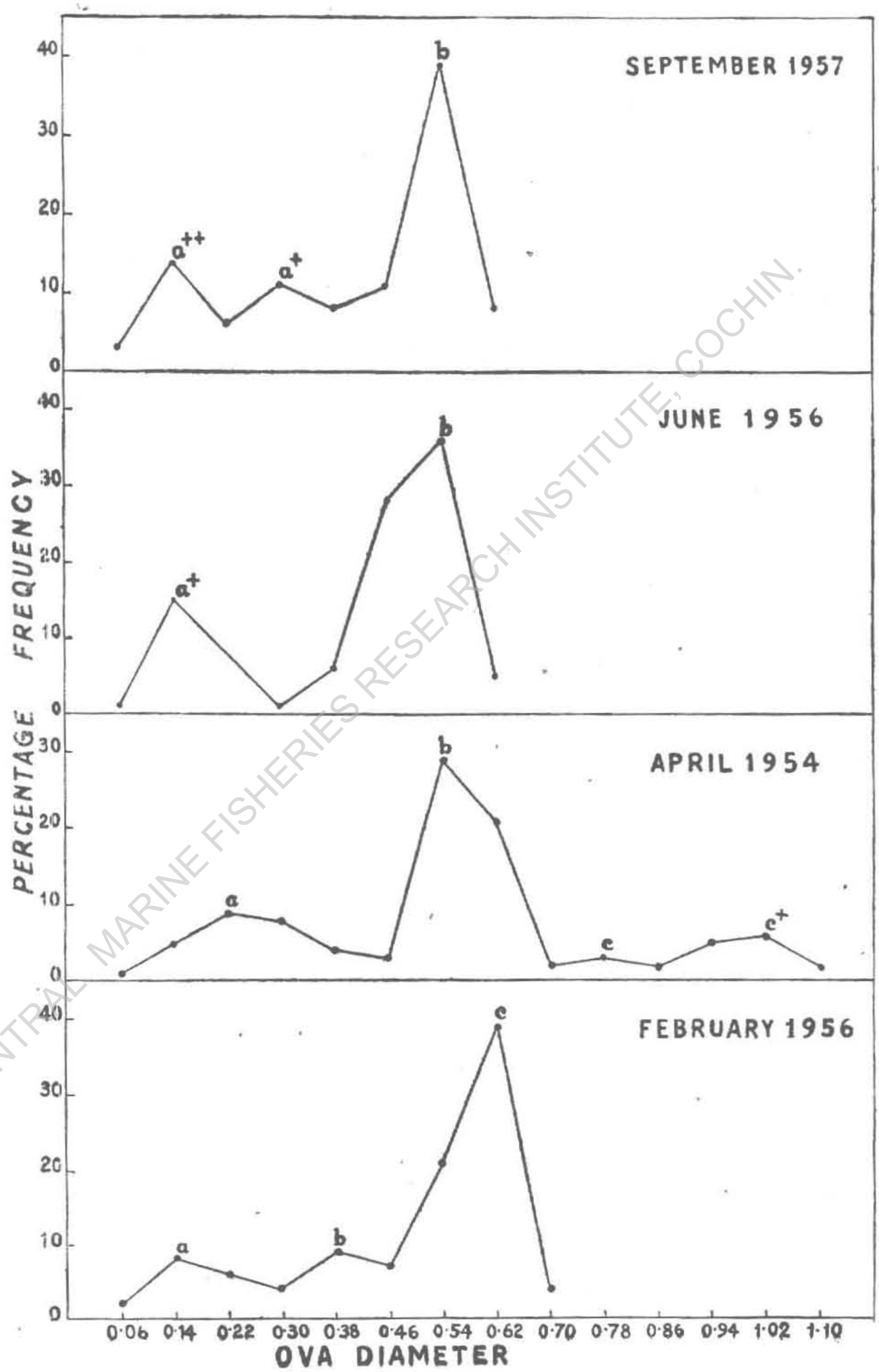

FIG. 7. Frequency polygons of ova diameter of *P. indicus*.

the probability that *P. indicus* spawns twice and also from the appearance of the young ones for the second time in January in a year it is suggested that the second spawning season appears to be during October to December. Thirdly, Gnanamuthu (1958) states that *P. indicus* enters the Madras inshore waters in September and breeds in November. The pro-larvæ become post-larvæ in forty-eight hours after hatching and grow into juveniles in thirty days. This may also be true in the case of the 'Dara' fishery of the Bombay coast regarding its second spawning season. And lastly, the probability that *P. indicus* spawns twice a year is further corroborated by the occurrence of what may be described as one year and one and a half year or two years and two and a half year classes at the same time in the Dwarka landings as described previously.

During the course of this study no spawning specimen was landed either by the trawlers or by the local fishermen from Bombay and Cambay regions, in spite of the fact that huge quantities of 'Dara' were landed during the last seven years. Mohamed (*loc. cit.*) has reported that mature specimens caught from Cambay regions are mostly females, the males being almost absent. The same has also been observed during the present investigation. He further states that *P. indicus* collected from the Satpati fishing village in April were almost entirely mature male specimens. Satpati fishermen stay away for fishing for three to five days. In order to keep the catch in fresh condition they remove the complete viscera from the fish. Due to this process of degutting, it is almost impossible to observe the gonadic condition of female specimens as the ovaries are removed along with the entrails.

The only one spawning specimen that was examined was from Sachana near Jamnagar. Shrivatsa (1953) mentions that Jew fishes and Indian salmons enter the Gulf of Cutch for spawning in March. Therefore, the breeding grounds of 'Dara' appear to be in the Gulf of Cutch. Satpati fishermen are understood to go northwards towards the Gulf of Cambay, as the summer advances for fishing. It may be because this fish is entering the upper reaches of Gulf of Cambay at that time.

For fecundity studies, two specimens measuring 93·8 and 95·0 cm. in the maturing condition were examined. They were estimated to contain 1,172,040 and 1,553,773 ova respectively.

Summary

1. Some aspects of the fishery and biology of *Polydactylus indicus* (locally known as 'Dara'), one of the main commercial species along the Bombay and Saurashtra coasts are presented and discussed.

2. Fully grown maturing 'Dara' are found in good numbers in the Bombay and Cambay regions. The fishery is well exploited by the fishermen of Satpati and Dahanu by the use of bottom-set gill-nets.

3. 'Chelna,' the immature 'Dara', are landed mainly from the Dwarka region by the trawlers. The areas K and M are extremely rich grounds for the 'Chelna' fishery. They form nearly 30·0% of the total catch during the season.

4. Study of growth in *P. indicus* was attempted by the method of length-frequency analysis. 3,376 specimens collected from the Dwarka region were measured. The Dwarka fishery seems to consist of the First, Second and Third year classes as well as the intermediary classes of one and a half and two and a half years.

5. *P. indicus* appears to spawn twice in a year once in April to June and again in October to December.

6. Fecundity studies indicate a high rate of recruitment.

Acknowledgement

It is a great pleasure to thank Dr. S. Jones for going through the typescript and making useful suggestions. I express my gratitude to Sarvashri R. Jayaraman and S. V. Bapat for their kind help in the preparation of this paper.

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J. Mar. biol. Ass. India, 1959, **1** (2)

OCCURRENCE OF HERMAPHRODITISM IN *POLYNEMUS HEPTADACTYLUS* CUV. & VAL.

Hermaphroditism which is very common among the invertebrates occurs as an anomaly in fishes. While in *Serranus* spp. this phenomenon prevails as a normal condition, it is observed as an abnormal feature of variable frequency in teleosts like Herring, Cod, Mackerel and some of the Pleuronectidae.

During the biological investigations of *Polynemus heptadactylus*, it was noticed that hermaphroditism is of somewhat common occurrence in this species. From October 1958 to January 1959, 385 specimens were examined from the local and trawler landings at Bombay. It was very interesting to note that nearly 10% of them were hermaphrodites and their percentages in the samples varied from 2 to 18 in the four different months.

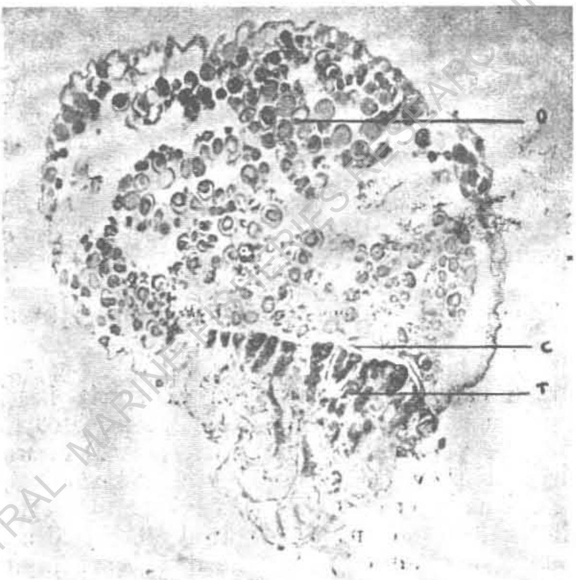

FIG. 1. T. S. of an ovotestis of *Polynemus heptadactylus* (O-ovary ; C-connective tissue ; T-testis). × 110.

Hermaphroditism in *P. heptadactylus* is found in the form of a pair of ovotestes. In fresh specimens, the two portions of an ovotestis are quite distinct from each other. The male portions of the two ovotestes face each other on the inner side while the female portions lie away from each other on the body wall. Further, the testis extends from end to end of an ovotestis and is milky white in colour whereas the ovary is either transparent as in the immature stage or yellow as in the maturing or mature stage.

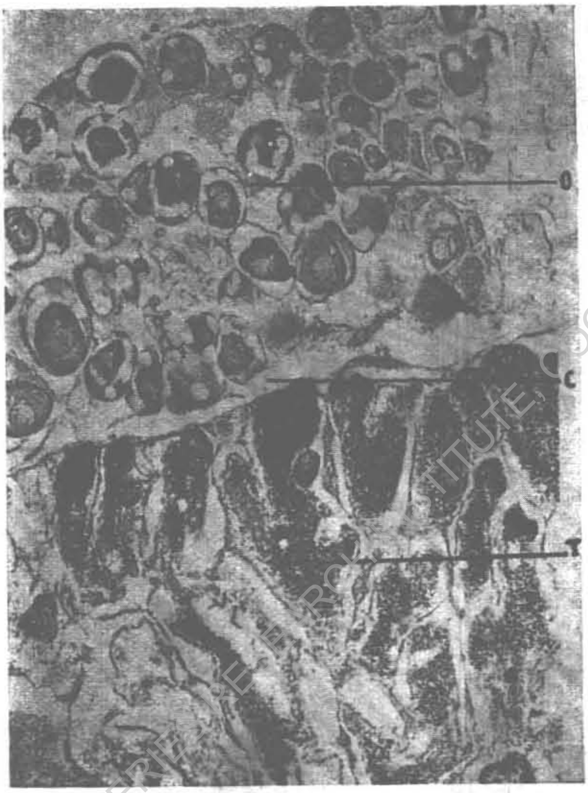

FIG. 2. T. S. of an ovotestis of *Polynemus heptadactylus* (Details of lettering same as above). × 550.

The hermaphrodite nature of the gonads in this species has been verified by studying the micro-sections stained with Delafield's hematoxylin and counter-stained with eosin. The photomicrographs (Figs. 1 & 2) of transverse sections of an immature ovotestis show that testis occupies comparatively a very narrow space. A connective tissue layer distinctly separates the two regions of an ovotestis. The lobules in the testis are smaller and in it are lodged a number of spermatocytes whose nuclei are stained deep. The more spreading ovary has larger ovigerous lamellae with a number of oocytes in it.

Hermaphroditism in *P. heptadactylus* has been noticed even in the advanced and spent conditions of the gonads. So it is doubtful whether there is any sex-reversal in this species.

Central Marine Fisheries Research Sub-Station,
Bombay 1.

P. D. NAYAK

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PRAWN CATCHES BY MECHANISED VESSELS IN THE TRAWLING GROUNDS OF BOMBAY AND SAURASHTRA.

P.V. Kagwade

Central Marine Fisheries Research Institute,
Mandapam Camp, India.

The relative abundance in the regional, seasonal and depth-wise distributions of prawns between latitudes 16°N, south of Bombay, and 23°N, of Kutch, based on the landings of two sets of bull-trawlers, 'Arnalla-Paj' and 'Satpati-Pilotan' of the New India Fisheries Company, and of the otter trawlers M.F.V. 'Jheenga', M.F.V. 'Bumili', M.L.'Meera' and M.L.'Sagarkanti' of the Government of India Deep Sea Fishing Station, Bombay has been studied.

The average annual yields of 20,690 kg of prawns forming 0.63% and 8,367 kg. forming 2.04% of the total catches of fish were obtained by the bull-trawlers for the period 1956-'63 and the Government of India vessels for 1961-'64 respectively. The highest catch of 38,604 kg. of prawns was obtained in 1962 for the bull trawlers with 9.78 kg per hour of trawling and 10,540 kg. for Government of India vessels in 1961 with a catch rate of 6.04 kg. per trawling hour.

Taking Bombay and Saurashtra together it has been observed that the prawn catches begin to increase from April-May and peak catches are obtained in some of the months from July to

September and occasionally even October as in 1961.

The fishing operations were generally in the 8m. to 70 m. depth ranges which have been considered in detail region-wise.

The prawn resources in trawling grounds appear to increase from north to southwards along the West Coast. While in Kutch to Veraval region, the catches have been either poor or only moderate, in Cambay and Bombay regions they have been fairly good. The annual average in percentage of prawns in Kutch to Bombay region ranged between 0.16 to 1.29.

Metapenaeus affinis, *M. monoceros*, *M. dobsonii*, *Penaeus indicus* and *Parapenaeopsis stylifera* are the common species of the Bombay and Saurashtra waters.

(Abstract 119 of Paper 'Symposium on Crustacea' held under the Auspices of The Marine Biological Association of India at the Oceanographic Laboratory, University of Kerala, Ernakulam, 1965)
